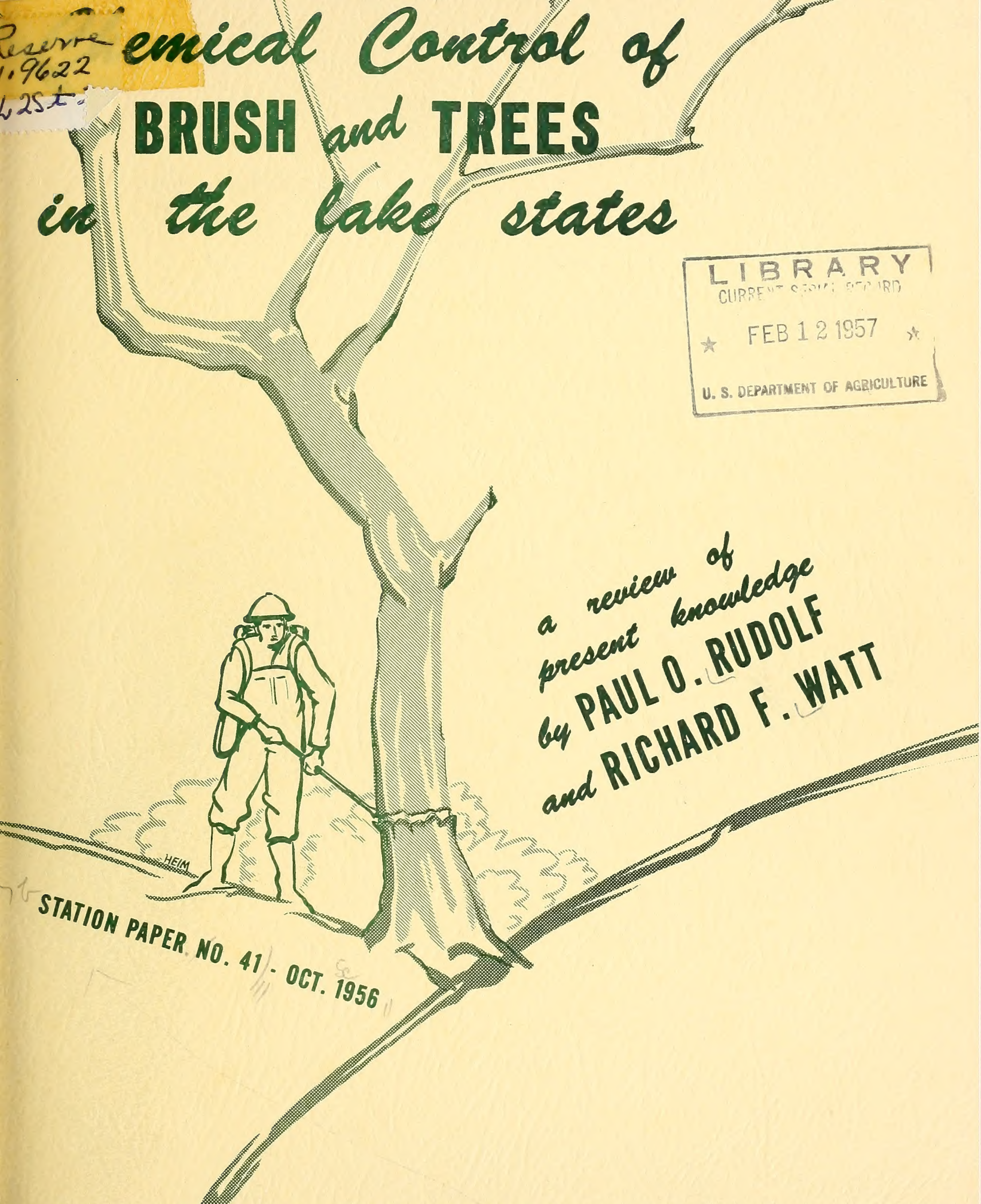
[Ch]emical Control of BRUSH and TREES in the lake states



a review of present knowledge

by PAUL O. RUDOLF
and RICHARD F. WATT

STATION PAPER NO. 41 - OCT. 1956

LAKE STATES FOREST EXPERIMENT STATION —— M. B. DICKERMAN, DIRECTOR
FOREST SERVICE —— U. S. DEPARTMENT OF AGRICULTURE

Early in 1951 the Lake States Forest Experiment Station published a paper on Chemical Control of Brush and Tree Growth for the Lake States (Miscellaneous Report No. 15) by Paul O. Rudolf. The report has been and still is in great demand. The rapid advance of research in the field of woody-plant control, however, has made revision desirable. The present report, revised by Richard F. Watt, includes much new material on chemicals, formulations, and methods of application developed during the past few years.

CONTENTS

CHEMICAL CONTROL OF BRUSH AND TREES IN THE LAKE STATES

A REVIEW OF PRESENT KNOWLEDGE 1/

by

Paul O. Rudolf and Richard F. Watt, Foresters
Lake States Forest Experiment Station 2/

INTRODUCTION

Woody plants must often be controlled on areas used by man. In forestry, encroachment of brush and trees on firebreaks, trails, telephone and powerline rights-of-way, and plantations must be prevented or controlled. Furthermore, unwanted woody plants must be curbed on areas being prepared for natural or artificial regeneration. Often the less valuable trees must be removed in cultural operations in forest stands. In other fields of activity also, woody plants may present problems of control. Farmers, highway and railroad officials, and utility line operators often encounter the problem of eliminating woody growth from their properties. In the past, mechanical methods have been most commonly used; on occasion, fire has been employed with success. However, during the last 10 years a number of chemicals have been developed which permit replacement of older methods with considerable savings in costs. As a result, much of the present control of unwanted woody-plant growth is now accomplished with chemical rather than mechanical means.

New chemicals and formulations and methods of application have been developed so rapidly in recent years and have been applied in so many different ways to a great many woody-plant species that it is difficult for workers to stay abreast of developments. It has become desirable, therefore, to summarize present knowledge of chemical control of woody plants even though the material will remain up to date but momentarily. Accordingly, this report brings together a brief summary of findings applicable to Lake States conditions and species.

1/ This paper is a revision by Richard F. Watt of Miscellaneous Report No. 15, prepared in 1951 by Paul O. Rudolf.

2/ Maintained by the Forest Service, U. S. Department of Agriculture, at St. Paul 1, Minn., in cooperation with the University of Minnesota.

KINDS OF

CHEMICAL HERBICIDES 3/

Ideally, a chemical herbicide should not only be effective in killing weed species but also reasonable in cost, easy to handle and apply, safe to use, non-toxic to higher animals, and non-corrosive to equipment. Many of the older herbicides were deficient in one or more of these requirements.

On the basis of type of action on the plant, chemical herbicides may be classed as (1) contact poisons, (2) soil sterilants, which poison the soil and kill by being taken into the roots, and (3) systemic poisons, which are absorbed and translocated throughout the plant. Some herbicides may kill by combinations of these methods. For most forestry purposes, the contact poisons have little use, for they do not kill the underground portions of the plant, which may produce a prolific growth of vigorous sprouts. The soil poisons have some value in maintaining vegetation-free strips such as are needed for firebreaks, but their use is still rather limited because large quantities are required and they are effective for relatively short periods (77). Systemic poisons are most desirable for brush control, for they may kill both tops and roots, eliminating the problem of subsequent sprout control.

Some chemical herbicides are selective, injuring or killing certain species or groups of species but not harming others. Others will kill all forms of vegetation. Both types are useful in forestry. The selective kinds are needed for such operations as releasing young conifers overtopped by broadleaf brush or trees. The non-selective kinds may be preferred on right-of-way brush control and similar situations where a general kill is sought.

OLDER HERBICIDES

Although chemicals may be thought of as a new tool in the control of vegetation, the writing of Caesar tells how the Roman legions rendered sterile the fields of the conquered Carthaginians by applying common salt, sodium chloride. Since those early days, chemical control of weeds has been practiced with indifferent success until recent years when more effective chemicals were developed.

3/ "Herbicide" is used here in the dictionary sense--weed killer. The term "silvicide" is sometimes used to designate materials for killing woody plants.

Sodium Arsenite

Since the late 1920's sodium arsenite has been used in controlling woody vegetation by application to cut stumps or through incisions in the bark. This chemical is highly toxic, the arsenic ion reacting violently with protoplasm, denaturing and killing it. The solution is mildly alkaline and highly buffered; the chemical, therefore, easily enters the plant cuticle by its hydrolyzing action (19). Sodium arsenite is non-selective, is translocated, and kills quickly. Unfortunately, it is also highly toxic to animal life and thus is dangerous to the user and any wildlife or livestock that may be attracted by its taste. However, by using tabs of blotting paper soaked in sodium arsenite solution and a special spud for inserting the tabs under the bark, trees can be killed with arsenite without danger to wildlife (73). This chemical has largely been replaced, except for chemical debarking, by newer safer ones that have been developed in the last 10 years.

Others

Such chemicals as other arsenicals, sodium chlorate, ammonium thiocyanate, and 27° diesel oil also proved reasonably effective in controlling woody plants (38). However, all these materials were either expensive in the quantities needed, or hazardous to use. Creosote, copper sulfate, zinc chloride, ammonium sulfamide, ammonium nitrate, and sodium nitrate have been found rather ineffective in killing woody plants (11).

NEWER HERBICIDES

Within the last 10 years new chemicals have been developed that are effective as herbicides and are non-poisonous to humans and animals. They are ammonium sulfamate, and various derivatives of the phenoxyacetic acids and related compounds. All these chemicals are translocated by plants and are sometimes effective in killing both the aerial and underground portions of plants.

Ammonium Sulfamate

Ammonium sulfamate is a relatively simple salt marketed under the name "Ammate." It is a non-selective chemical that can be used as a foliage spray or may be applied to cut surfaces. The chemical is supplied as yellowish crystals, which are highly soluble in water. The crystals are deliquescent, making storage a problem in high humidity areas. Ammate is highly corrosive to most metals used in spray equipment, a major disadvantage of the chemical. Equipment used for spraying Ammate solutions must be promptly and thoroughly washed out before serious damage results.

The toxic action of Ammate is not well understood. Sulfamic acid is fairly strong; any acid strong enough to overcome the buffering action and markedly change the pH of the cell will kill it by decomposition of the chlorophyll, denaturing of the protoplasm, and disorganizing of the nucleus. In addition, ammonium salts are often highly dissociated and somewhat corrosive (19).

Ammate is essentially non-selective, but some differences in response of species have been observed, especially in respect to its effectiveness on sprouting (54). Relatively large amounts of Ammate are needed for foliage spraying--100 to 400 pounds per acre--(36), so that it has been superseded by the hormone-type chemicals which can do the job at considerably less cost. However, Ammate is a desirable chemical for killing large individual trees. Ammate crystals placed in notches in the base of oak, aspen, and maple over 4 inches in diameter gave nearly 100 percent top-kill in all seasons with a great reduction of sprouting over that obtained with only felling of the trees; similar results were obtained in treating the stumps of smaller trees (9).

Season of application did not seem to affect the results with southern hardwoods (39), but midsummer applications were best for ponderosa pine (35) and growing season applications were recommended for Ammate poisoning in notches in the Northeastern States (46). However, a test with hardwoods in Michigan gave good top-kill at all seasons of the year (9). One study indicated the poison to be much more effective when applied early in the morning than in the afternoon or evening (60).

Experiments with privet and mockernut hickory disclosed that Ammate moves upward rapidly in the xylem and downward slowly in the phloem (12). Since movement in the xylem is most rapid in the growing season when transpiration is high, this relationship was advanced to explain why the best root kill with notching is obtained in the dormant season when the upward movement of fluids is lowest. The slow downward movement of Ammate also explains the importance of placing the chemical near the base of the tree to obtain good kill of the roots. With a few exceptions, such as hazel, most woody plants sprout quite vigorously after having been killed back by Ammate early in the growing season (22).

Ammate is readily translocated as indicated by the killing of standing aspen trees adjacent to the poisoned stumps of 90-year-old individuals of the same species (58). In another case, red pines were killed by application to nearby aspen, even though no root grafts were found between the poisoned aspen and the affected pine (3). White pines have been killed by spraying of poison ivy growing under the trees (79). It has been found that Ammate, sodium arsenite, and sodium chlorate can be translocated from one red oak to another through natural root grafts, although 2,4,5-T apparently cannot (42). These cases illustrate that caution must be used in applying this or other herbicides in the vicinity of trees or shrubs that are to be saved.

Growth-Regulating Chemicals

In recent years various chemicals have been developed that act as growth hormones when absorbed by the plants. Foremost among these for woody-plant control are derivatives of 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). Other somewhat similarly acting chemicals include 2,4,5-TP (2,4,5-trichlorophenoxypropionic acid), MCP (2-methyl-4-chlorophenoxyacetic acid), and maleic hydrazide. These chemicals are effective in comparatively small amounts and change the physiological activities of the plants to cause eventual death.

These hormone-type herbicides cause a variety of reactions in plants, some readily discernible in outward characteristics of the plant, others discernible only by complex biochemical testing. Curling, twisting, and death of the stems and leaves of sprayed plants is one of the most obvious responses. Other responses are proliferation of stem tissues, destruction of the phloem, disorganization and rupture of the cortex of roots, increase of respiration, lowering of carbohydrates, and interference with native auxins and with physiological and enzymatic processes (78). Because the action of the hormones is so closely associated with the physiological condition of the plant, the reactions of plants may vary widely with the different conditions under which they are growing. Generally, when the conditions are favorable for the rapid photosynthesis and production of food in excess of the needs of the leaves, conditions are good for successful application of the herbicide. The herbicides are conducted throughout the plants in connection with the movement of carbohydrates, so that application of herbicides when plants are actively manufacturing and transporting food is desirable. This occurs, of course, after the plant has been exposed to strong light at temperatures of 65° to 90° F. in the presence of ample water and mineral nutrients. Physiologically, the afternoon is an ideal time for foliage spraying.

Hormone-type herbicides penetrate the cuticle of leaves readily and quickly, although plants with a heavy waxy cuticle appear to be more resistant to penetration by the chemicals (74). Rain as soon as one-half hour after application had no effect on the action of ester formulations, but reduced the effectiveness of water-soluble salts applied in weak solutions (55). Downward movement of the herbicides is slow and polar, so vertical roots are more readily killed than horizontal ones (19). This may explain some of the difficulty in preventing suckering in aspen. Application of herbicides as a basal spray or in a frill is believed to have the effect of a girdle rather than that of a hormone that kills by being translocated to other portions of the tree. This is borne out by the need to drench thoroughly the root crown of trees in basal spraying for best control of sprouting.

Hormone-type herbicides are available in a large number of compounds; the herbicidal effectiveness varies with the derivative used. Using herbaceous plants as test material, the effectiveness in descending order was isopropyl ester, alkanolamine salt, the acid, and the ammonium, sodium, and calcium salts; these tests were made with both 2,4-D and 2,4,5-T (53). Because of the similarity of the order, it is probable that this order will hold with other similar compounds such as 2,4,5-TP.

Most commonly used for forestry purposes are the esters. The low-volatile esters have been found best for woody plants, although the more volatile ones are also effective. The esters, produced by reaction of the acid with various alcohols, are liquids that are miscible in oil and are often applied in oil solutions. With suitable emulsifiers, the esters can be mixed with water or oil and water for spraying as emulsions. The pure acid is seldom used as a spray, for difficulties may be encountered in keeping the acid in solution when mixed with water or oil. However, special formulations are available that contain additives to keep the acid in solution when mixed for spraying. Various salts of the acids have also been prepared, but these water-soluble powders are not as effective as the esters on woody plants. However, the amines have recently been used in high concentration for frilling and show promise in such applications (75). Generally, oil solutions or oil-water emulsions with considerable oil are more effective than sprays with little oil, perhaps because of better penetration of the waxy cuticle. However, since some oils are toxic, it is possible to so burn the leaves before the herbicide is absorbed that effectiveness is decreased. The addition of wetting agents or fructose increases toxicity; proprietary preparations are produced with various adjuvants to increase activity.

2,4-D (2,4-dichlorophenoxyacetic acid)

The first hormone-type chemical to be used to any extent in the control of woody plants was 2,4-D. It is quite selective and is effective on alder, elder, black locust, sumac, and willows, but rather ineffective on oaks, hickories, ashes, maples, and most conifers. Closely related forms can be manufactured which vary in the amount of chlorine in the molecule. 2,4-monochlorophenoxyacetic acid was more specific than the dichloro-form which, in turn, was more specific than the trichloro-form when tested on a number of ribes species (55). 2,4-D is somewhat cheaper than the newer 2,4,5-T and is, therefore, more economical to use on plants susceptible to it. It is often combined with 2,4,5-T in various proportions, usually 1:1, to give the so-called "brushkillers" which are effective on a wider variety of plants than the 2,4-D alone. However, addition of 2,4-D to 2,4,5-T may lower the effectiveness of the 2,4,5-T to plants that are resistant to 2,4-D (55). Late-season spraying of 3 pounds a.h.g. (acid equivalent per hundred gallons of spray) of 2,4,5-T obtained results equivalent to that given with 4 pounds a.h.g. of "brushkiller" (18). The trend is now toward replacement of "brushkiller" with 2,4,5-T alone when treating a mixture of species some of which may be susceptible to control by 2,4-D alone.

2,4,5-T (2,4,5-trichlorophenoxyacetic acid)

The chemical 2,4,5-T entered the herbicide picture at a later date than 2,4-D but, because of its effectiveness on a wider variety of plants, has come into increasingly wider use in woody-plant control. Plants susceptible to 2,4-D are susceptible to 2,4,5-T; many plants resistant to 2,4-D are susceptible to 2,4,5-T. Better control of sprouting usually is obtained with 2,4,5-T. It is available in the same basic forms as 2,4-D, that is, acid, salts, amines, and esters. Again, the low-volatile esters of 2,4,5-T have been found the most effective in the control of woody plants.

2,4,5-TP (2,4,5-trichlorophenoxypropionic acid)

The chemical 2,4,5-TP is a relative newcomer to the field of brush control, and its potentialities are just beginning to be discovered. Like 2,4-D and 2,4,5-T, it can be formulated in a variety of compounds, but has been used on brush only in the low-volatile ester form. It has been found more effective as a foliage spray at 3 pounds a.h.g. than similar applications of 2,4,5-T and brushkiller on three species of maple (24), although other tests showed about the same kill as 2,4,5-T on maple and on a wide variety of other species (17).

Others

The chemical industry is active in developing new chemicals that may prove to be effective in the control of brush. Considerable testing is necessary to determine the conditions under which these may be effective. Some of the newer ones are mentioned briefly below. They have not yet displaced the older 2,4-D and 2,4,5-T, but additional tests are needed to disclose their potentialities.

Aminotriazole (3-amino, 1,2,4-triazole) has been used with good results on a number of species. Water solutions with 2 pounds per 100 gallons have given good results on western snowberry (*Symphoricarpos occidentalis*) and poison ivy (47, 48); at 6-pound concentrations black cherry, oak, ash, and hickory were killed (50). However, sumac, red maple, and sassafras recovered following initial injury by this chemical. The chemical is translocated by the plant: it often results in albinism the second year after treatment, followed soon by death.

Esters of 2,4-DP (2,4-dichlorophenoxypropionic acid) have been formulated and tested in foliage spraying at 4 pounds a.h.g. on white and red oaks and black cherry, and were found to be more effective than 2,4,5-TP, 2,4,5-T, and MCP propionic tested nearby (51). More testing is needed to explore the promising potentialities of this chemical.

MCP (2-methyl-4-chlorophenoxyacetic acid) has been used in tests in both the amine and ester formulations. Basal sprays in oil gave good results on prickly ash (33) and barberry (49); foliage sprays on *Symphoricarpos occidentalis*, *Rosa* spp., and chokecherry were not as effective as 2,4-D or 2,4,5-T (56).

Dinitro weed killers, complicated organic compounds used as yellow dyes, are selective herbicides in weak solutions but nonselective in strong ones. They are poisonous and inflammable under some conditions, but can be used without danger if reasonable care is exercised. Dinitro ortho secondary butyl phenol, DNOSP, has been fairly effective as a stem spray in killing alder, aspen, and hawthorn. It kills leaves and stems rapidly when applied as a foliage spray, but vigorous sprouting follows (21).

TCA (sodium trichloroacetate) has been used mainly to control grasses, but also injures many trees and shrubs. It kills largely as a soil poison. The soil may remain toxic for from a few weeks to as long as a year or more (41). For example, red pine seedlings spring-planted in an area treated with 75 to 100 pounds of TCA the previous fall suffered considerable leaf burning; in another test, red pine transplants were uninjured. Seedlings were also uninjured when planted at least 3 months after treating the soil with 50 pounds or less of TCA per acre, but suffered severely when transplanted into soil treated 6 weeks previously (34). Fall applications gave no reduction in germination or survival of seedlings transplanted the following spring. Post-emergent sprays on 6-week-old jack pine, however, gave 100 percent mortality (43). Addition of TCA to systemic herbicides resulted in better top-kill and sprout control (56).

CMU (3-(p-chlorophenyl)-1, 1-dimethylurea) is another soil poison that has been used to kill trees and brush. Scrub oaks were killed with application of 50 pounds of pellets per acre (28). Dosage of 11 pounds or more controlled oak and grasses on southern planting sites; 2 to 3 years were required to kill the oak. However, slash pine planted 9 months after application suffered high mortality. In the sandy soils of this treated area biological activity is low and CMU persists for a long time (77).

Other chemicals tried on woody plants are sodium monochloroacetate, which was used successfully in frill girdles on aspen (23), and 2,3,6-trichlorobenzoic acid used on oak, willow, and hazel as an effective foliage spray (57).

Indirect Effects of These Herbicides

The hormone sprays and Ammate are not directly poisonous to men or animals, but they do have some indirect effects. For example, some people are allergic to the hormone herbicides; also, gloves soaked in Ammate solution may cause skin irritation. Oil solutions spilled on clothing may cause burning of the skin.

Spraying of foliage available to wildlife or domestic stock does not appear to have any important effect upon the health of the animal that may subsequently eat it. A study of pasture spraying with concentration 2 to 4 times greater than recommended for weed control disclosed no serious physiological effects upon the livestock involved; in no case was a sprayed area preferred to the unsprayed one, although the area sprayed with 2,4-D was grazed almost as well as the unsprayed (31). Chokecherry foliage, which contains hydrocyanic acid in sufficient amounts to be poisonous to livestock, showed a progressive decrease in hydrocyanic acid following spraying with 2,4-D, 2,4,5-T, or Ammate (30).

APPLYING THE HERBICIDES

Herbicides may be applied in a variety of ways. They may be sprayed on the foliage, the base of stems, or cut stumps, or in frills or girdles in the bark. Ammonium sulfamate crystals may be placed on the surface of freshly cut stumps or in notches cut into the bole. Depending upon the purpose for which they are used, the herbicides may be applied at several seasons, in various formulations, at a number of rates and concentrations, and by a wide variety of equipment. No one method is best for all conditions; no one chemical is superior in all cases. Although prescriptions can be given that will be highly successful in the majority of cases, there still remains an element of uncertainty in some cases because the response of the vegetation may be unfavorably affected by the physiological condition of the plant.

KINDS OF APPLICATION

Foliage Sprays

Foliage sprays have been the most common method of applying the newer chemical herbicides. Such sprays have been used on plants up to 30 feet tall, but until aerial spray methods were developed they were, in practice, limited to brush about 6 feet tall with density not too great to prevent good penetration of the mass of foliage. Early specifications for ground foliage spraying stipulated that the foliage be wetted to the point of runoff, requiring as much as several hundred gallons per acre. More recently, spraying with as low as 40 gallons per acre has given good results (56, 63). Much smaller quantities have been used successfully in aerial spraying. Foliage sprays are usually applied at the full leaf stage of the plant but before the end of the growing season when plant activity is low. Concentrations of hormone sprays of 1,000 to 4,000 p.p.m. (parts per million) or 1 to 4 pounds a.h.g. are used. Ammonium sulfamate is used at about 1 pound per gallon of water. Solutions of chemicals that are too strong may result in burning of the tissue at the point of application with little or no translocation and consequently little lasting effect.

Salts and amines of hormone herbicides, little used now in woody-plant control, may be applied in water sprays or in oil-water emulsions by the addition of an emulsifying agent. Esters are soluble in oil and form emulsions when properly dispersed in water. Water and oil-water emulsions are commonly used for ground application of foliage sprays where the large volume of spray required obviates the use of large percentages of oil. Kerosene, diesel, and light fuel oils are commonly used in preparing the oil-water emulsions.

Airplane spraying is the newest method of applying foliage sprays, and, although still a relatively poorly known procedure, it has found widespread acceptance because of the large areas that can be treated in a short time and at relatively low cost per acre (66). Even if the original treatment is not highly successful, the costs are so low that a number of airplane applications can be tried before the cost equals that of ground spraying or mechanical operations. Aerial spraying also can be used on areas of low accessibility where ground methods would be impossible or of prohibitive cost.

The hormone-type herbicides are used in aerial spraying. One to two pounds acid equivalent per acre are usually sufficient. This amount is applied at from 2 to 5 gallons per acre, usually in oil or oil-water emulsions and sometimes in water alone (59, 64). Airplane application holds much promise for treatment of brush prior to planting, for release of conifers from overtopping trees and brush, and in manipulation of cover for the encouragement of various species of wildlife (6) (fig. 1).

Much remains to be discovered about the effects of time of application and the amount and kind of sprays before a sound basis is reached for aerial spraying.

Figure 1.--Red pine plantation released from overtopping hardwoods by aerial spraying.

Cut Surface Sprays

Brush and small trees may be cut and the stumps sprayed with herbicides. Such cut surface sprays are widely used, especially in areas where the aesthetic values would be injured by the presence of brown leaves and dead stems that follow foliage spraying. Cut surface sprays are also effective when the brush is over 6 feet tall or very dense. Cutting and spraying of stumps may be done throughout the year. Stumps should be cut high enough to be easily found at the time of treatment, and it has proved helpful to add color, such as Red-O, to the spray so that it is easy to tell which stumps have been treated and thus prevent misses. High stumps also take less labor. However, if the area must be readily accessible in the future, high stumps should be avoided. The tops and sides of the stumps should be drenched to the point of runoff immediately after cutting. Depending on the area, several cutters will be needed to keep one sprayer busy. Power mowers can often be used advantageously for cutting small brush before spraying.

Cut surface sprays should be more concentrated than foliage sprays. About 10,000 to 50,000 p.p.m., or 5 to 30 pounds a.h.g. of hormone sprays in oil, or 2 to 9 pounds of Ammate per gallon of water, ordinarily are used. It is important that runoff occurs so that sprouting from the root collar is minimized. This is probably the most effective method of eliminating brush and preventing subsequent sprouting, for the herbicides are applied close to the root collar where much of the sprouting would occur. Litter about the root crown of the plants may hinder thorough wetting of this part of the plant (72); standing water may also prevent sufficient chemical reaching the crown (2). Otherwise, season of application is unimportant.

Basal Sprays

Basal sprays have also been used with good results. Concentrated solutions of herbicides in oil are applied to the lower 1 or 2 feet of the stem and entirely around it to the point of runoff. Such basal sprays have been very effective during the dormant season when the foliage sprays, of course, cannot be used. Early spring treatment should be avoided when maximum control of sprouting is required (9). The volume of spray applied in basal spraying is very important. Experiments have shown that the spray should run down onto the root collar, for downward movement of herbicides in the plant is slow. Applications to brush standing in several inches of water have been ineffective, presumably because the water prevented the spray from reaching the root collar (2).

Apparently the effect of basal sprays is to girdle the tree and to kill dormant buds at the ground level. Concentrations of 4 to 16 pounds a.h.g. are used in oil solution, although, on occasion, as high as 42 pounds a.h.g. have been recommended (55).

Generally, 2,4,5-T has proven most effective for basal spraying, although there are instances where 2,4-D may be used on highly susceptible vegetation.

Axe Cuts, Girdles, Frills, Holes, or Notches

Axe cuts, girdles, frills, holes, or notches through which herbicides may be introduced into the sapstream of the plant often are used to kill larger trees. Both ammonium sulfamate and the hormone-type herbicides are used in this way. Again, as with the basal sprays, the lower the position of application the better the control of sprouting (8). Girdling without the use of chemical will usually kill a tree if carefully done, but the chemicals often do the job quicker, control sprouting to a greater extent, and may penetrate sideways into areas where girdling is not complete, giving a better kill than girdling alone. Frill girdling, a single row of overlapping axe cuts penetrating into the wood, will not kill a tree unless herbicides are placed in the cuts. However, because it does not require so much cutting with hand tools, it reduces the danger of accidents and labor costs may be lower.

A number of tools can be used for preparing the trees for treatment. Notches or cups cut into the tree trunk can, of course, best be made with an axe. This tool is also most effective for frilling. Some workers prefer a heavy axe with which the bark and wood can be penetrated easily even in cramped quarters where the swing is limited; others use light axes. Power saws, gasoline-powered girdlers such as the "Little Beaver," spuds, and simply bumping off the bark with the back of an axe can be used to expose the living tissues for application of herbicides, but frill girdling with an axe is probably more efficient than any of these methods. The "Cornell Tool," a hollow-handled, spud-like tool, simultaneously cuts the bark and inserts a limited amount of chemical into the incision. The "Council Tool," a single-bitted axe with a punch on the back, can be used to quickly punch out the hole into which chemical solutions may be poured.

Hormone-type herbicides for application in girdles, frills, and holes are used at 4 to 16 pounds a.h.g. in either oil or water. However, oil solutions are preferable; 4 pounds a.h.g. of 2,4,5-T in oil gave better results than 8 to 40 pounds in water (4). If the temperature is below freezing, water solutions cannot be used. Care should be taken in most applications to wet thoroughly the girdle or frill so that any unsevered portions of bark will be killed by lateral penetration of the chemicals. The herbicides should be applied immediately after exposure of the living tissue for best results. 2,4,5-T gives better top-kill and sprout control than does 2,4-D.

Ammate can be applied to cut surfaces either in a solution of 1 to 4 pounds per gallon of water or as crystals. For larger trees good results have been obtained by placing a tablespoonful of crystals in notches cut into the base of the tree and spaced about 6 inches apart around the circumference (70). Some workers have placed the notches closer together. On small stems that can easily be severed from the roots, a V-shaped cut is often made and about a tablespoonful of crystals placed on the stump. The deliquescent crystals rapidly absorb moisture from the wood and from the air and are dissolved and absorbed by the tree (fig. 2).

To reduce the volume of material that must be transported, experiments have been conducted using concentrations of 400 pounds a.h.g. of 2,4-D and 2,4,5-T (the concentration in which hormone-type herbicides are commonly sold) in frills. These treatments show promise of reducing costs, especially through use of the amines applied at the rate of 1 milliliter per inch of diameter (75).

SEASON OF APPLICATION

Season of application is important, for herbicides are translocated in the presence of carbohydrates. Therefore, best results are obtained in foliage spraying when the leaves are fully expanded and are synthesizing food beyond the needs of the leaves. At this time the food is being transported out of the leaf and the herbicide will move along with it (16). Presumably some will be transported to the roots. Furthermore, the ability of a plant to recover from killing of foliage and stems depends upon the food reserves available to

Figure 2.--Ammate crystals are placed in notches cut in large trees or in the tops of small stumps.

it to produce new sprout growth--another reason why the season of application is important. In deciduous plants and, to a lesser extent, coniferous ones, the rapid growth of foliage in the spring is sustained in a large part by the reserves stored either in the roots or in stems. These reserves are at a low point after completion of leaf growth but before the leaves can manufacture food beyond their own needs. Therefore, foliage spraying at about the full-leaf stage will result in minimum number and vigor of sprouts. For example, hazel sprayed in July produced fewer and less vigorous sprouts than those sprayed in June and August (61).

The time to cease foliage spraying in the fall is difficult to determine. Oak has been successfully sprayed even after the leaves have turned red (18), but it is safer to discontinue foliage spraying several weeks before the first frost until more is known about late-season spraying.

The season of application of basal sprays and cut surface treatments is less critical than with foliage spraying but nevertheless important. With these types of treatments, the chemicals are applied near the base of the plant. Killing is probably due largely to a girdling effect. Sprouting is often inhibited by application of chemicals directly to the root crown. Therefore, translocation, which is intimately associated with the stage of growth of the plant, is not as vital to successful control as in foliage spraying. Top-killing is usually good at all seasons of the year, but subsequent sprouting varies with the season of treatment. For example, aspen basal-sprayed between June and October produced no suckers, but trees sprayed at other times of the year did (5). November basal spraying of mountain maple gave better control of sprouting than did May spraying (62). Chemical frill girdling during July to October gave better sprout control than in other periods of the year (8). In all these tests, top-kill was equally good at all seasons. Thus, basal spraying and cut surface applications extend the season of treatment throughout the entire year, but only at the expense of sprout control.

CONCENTRATION AND RATES

Rates of application of the hormone sprays are often expressed in terms of pounds of acid equivalent. Commercial preparations usually contain 4 pounds acid equivalent per gallon. Concentration of sprays may be expressed in pounds of acid equivalent per hundred gallons of spray (a.h.g.). However, some workers express concentration in percentage or parts per million (p.p.m.). These two measures, which are on a weight basis, are not absolute because water and oil, the commonly used spray diluents, have different specific gravities. Also, percentage concentrations are sometimes expressed on a volume basis, adding to the difficulty of determining exactly how to mix a chemical to give a desired concentration in percentage or p.p.m. For these reasons, pounds of acid equivalent per hundred gallons is to be preferred. However, many of the publications consulted gave the concentration in p.p.m. or percent and are reported in that manner here.

Ammate solutions are usually reported in pounds of Ammate in gallons of water. Six pounds of Ammate dissolved in 1 gallon of water makes 1.4 gallons of spray solution (68).

For area treatments, rates are usually indicated in pounds of acid equivalent per acre. Spray equipment must be calibrated accurately to permit application of the desired amount of herbicide in the calculated concentration.

The following tables will permit conversion from one measure of concentration to another and indicate how to mix sprays to obtain desired concentrations. Table 1 shows how to mix solutions of desired concentrations in pounds of acid equivalent per 100 gallons of spray. The indicated amount of herbicide should have added to it sufficient diluent to make 100 gallons of spray. Table 2 can be used for approximate conversions from one measurement of concentration to another. Concentration by weight will remain constant regardless of the concentration of the formulation used to mix the spray. However, the concentration by volume will vary with the concentration of the formulation. This table is for herbicides of 4 pounds acid equivalent per gallon, the most common concentration supplied by manufacturers.

Table 1.--Amount of herbicide to use for sprays of different concentrations

When acid equivalent of herbicide is--	And required concentration of spray in pounds of acid per 100 gallons (a.h.g.) is--						
	2	4	6	8	12	16	20
	Use gallons of herbicide shown						
2.00 lbs./gal.	1.0	2.0	3.0	4.0	6.0	8.0	10.0
3.00 lbs./gal.	.7	1.3	2.0	2.7	4.0	5.3	6.7
3.34 lbs./gal.	.6	1.2	1.8	2.4	3.6	4.8	6.0
4.00 lbs./gal.	.5	1.0	1.5	2.0	3.0	4.0	5.0

Table 2.--Table for conversion from one measure of concentration to another 1/

WATER CARRIER

Concentration by weight of acid			Concentration by volume
P.p.m.	Percent	A.h.g.	Percent
2,500	0.25	2	0.5
5,000	.50	4	1.0
10,000	1.00	8	2.0
OIL CARRIER			
10,000	1.00	7	1.7
20,000	2.00	13	3.4
30,000	3.00	21	5.1

1/ For herbicides of 4 pounds acid equivalent per gallon.

EQUIPMENT NEEDED

Foliage sprays may be applied with a variety of equipment, ranging from small household spray guns for treatment of only a few plants to elaborate power sprayers and airplanes for large areas. For spot spraying and control of small patches of brush, 3- or 5-gallon knapsack sprayers are satisfactory (fig. 3). A high-pressure sprayer, the "Hi-Fog" gun, carrying 3½ quarts of spray and developing pressures up to 1,000 pounds, is sometimes used for application of small amounts of comparatively concentrated sprays in areas of difficult access (52). For right-of-way spraying, a wide variety of truck- or tractor-mounted power equipment with spray booms is available. Volumes as low as 10 gallons per acre can be applied with such equipment, but usually considerably more volume is used. They should be operated at low pressures of 30 to 100 pounds in areas where drift presents a problem. However, higher pressures are more efficient. Pressures that are too low result in poor coverage of leaves and stems, excessive runoff, and poor penetration into dense brush stands. For high-pressure spraying, power turbine blowers have worked well, using 30 to 40 gallons per acre. Special spray cars mounted by batteries of six spray guns have been used on railroad rights-of-way.

Figure 3.--Low-pressure knapsack sprayers may be used to apply basal sprays.

Fire equipment can be used for spraying by mounting portable pumps and barrels or tanks on truck beds, provided the rubber on the system is replaced by neoprene, which is not destroyed by the oil in the sprays (72).

For covering large areas, airplane application is perhaps the most economical method, although the techniques have not been worked out thoroughly enough to obtain consistent and effective results with every operation. The volumes applied per acre are quite low--from 2 to as much as 7 or 8 gallons per acre. Good distribution of such small volumes of spray is, of course, very difficult with slow-moving ground equipment. Herbicides used must be effective in small quantities because of the comparatively high cost of applying a given quantity of liquid from the air as compared to ground applications. For this reason the hormone-type herbicides, which produce good results when applied at the rate of 1 to 2 pounds acid equivalent per acre, have been used in aerial brush control spraying. Oil or oil-water emulsions have been found most satisfactory.

Because of the small size of the spray droplet produced by airplane equipment, the weather conditions for aerial application are critical. Spraying should not be attempted if wind movement is over 6 miles per hour, for then results will be spotty because of drift of the spray. The higher the proportion of oil in the spray, the greater the number of small droplets produced.

Light airplanes that can land on small fields or lakes near the point of application and are highly maneuverable are used for most aerial application, although in some instances where helicopters were used the applications cost only about 30 to 50 percent more than with fixed-wing aircraft (20). Helicopters are more maneuverable and are, therefore, more desirable in rough country than in flat country (26).

Basal sprays are applied at low pressures. Knapsack sprayers with U-tipped spray wands have been advocated to cover two sides of the tree simultaneously to give quicker and better coverage of the base of the bole (10), but they use more spray solution. Low-pressure, truck-mounted power sprayers with several hoses equipped with trigger-type shutoffs at the tip have been used for right-of-way basal spraying very successfully (72).

Herbicide spray equipment should be thoroughly cleaned before it is used for other purposes on susceptible plants. Solutions of ammonia or trisodium phosphate have been recommended for cleaning equipment used with hormone sprays. Ammate solutions will corrode metals very quickly, and serious damage will result if the equipment is not cleaned thoroughly soon after using by flushing with large quantities of water. Ammate spray that has drifted to associated equipment such as trucks or trailers should also be removed from them to prevent damage.

Frills, girdles, and cups are usually made with axes. The Cornell tool has been used for application of Ammate and hormone herbicides through the bark of individual trees.

Chemical solutions may be applied to frills, girdles, and cut surfaces with a low-pressure knapsack sprayer, a simple back-pack sprayer made from a 2-gallon oil can (15), or paint brushes or swabs in the case of Ammate. The low-pressure sprayers are preferable, however, for they do a faster job and can be used on the occasional frill that is placed too high to permit utilization of gravity flow.

The kind of nozzles used on spray equipment is important. For low-volume spraying with a knapsack sprayer, No. 59 or A90 "Monarch" nozzles or equivalent, or atomizing nozzles, have been recommended (67). Some prefer fog nozzles or "pecan" nozzles on high-pressure systems (67). For basal stem spray, the "Hi-Fog" gun with No. 3 or No. 4 nozzles, or knapsack sprayers with standard weed nozzles such as Spraying Systems No. 8004 or No. 6504, have given good results (1, 52). For stump treatment with knapsack sprayers, the full-jet No. 1 nozzle is good (1). Two-gallon oil cans have been adapted for application of chemicals to frills and girdles by attaching a hose with a clip-type tubing clamp and terminating with a 24-inch length of ¼-inch aluminum tubing. Such equipment is inexpensive and delivers a solid stream of fluid that can be directed into the frill or girdle with little waste through splashing (15).

In aircraft spraying, nozzles with ¼-inch openings have been used to cut down spray drift. Atomizing nozzles should not be used because the small spray particles produced will drift excessively. Nozzles that have individual diaphragms or a ball-check, insuring positive shutoff of spray at the end of the run, are desirable. The boom should be large enough to prevent a significant drop in pressure at the end nozzles and should be fitted with caps at the end to permit cleaning. There should be fewer nozzles in the 3- to 4-foot space left of center and more nozzles in the space right of center to compensate for the spray displacement caused by the propeller slip stream. Airplane spray equipment must be well calibrated to ensure the application of the limited volume of spray evenly and at the proper rate over the area.

COST OF
CHEMICAL BRUSH CONTROL

The cost of chemical control of woody plants depends on such factors as the kind of chemicals used; the rate and concentration; the method of application; the kind, size, and density of vegetation treated; the season of application; and the prevailing wage rate. These may well vary with each operation.

Cost of chemical and spray material is, of course, an important item. However, the per-pound cost may not be a good indication of treatment cost with a given chemical because the methods of application and the amount necessary to give control also are important. For example, it was found that similar results were obtained by using one part of 2,4,5-T or five parts of "brushkiller" in treating cut stumps (32). Thus, it was ultimately cheaper to use the more expensive 2,4,5-T than the "brushkiller." In foliage spraying, the large quantity of Ammate needed makes use of this cheap chemical more costly than spraying with the much more expensive hormone-type materials. Approximate price ranges for some of the common herbicides are (20):

Chemical	Cost per pound
2,4-D (acid equivalent)	$ 1.00 - 1.50
2,4,5-T (acid equivalent)	2.00 - 3.00
MCP (acid equivalent)	2.00 - 3.00
Ammonium sulfamate	.15 - .25
Arsenicals	.06 - .10
TCA	.45 - .60

Some costs reported for ground spraying of foliage are: $6 to $7 per acre to spray hazel brush averaging 20,000 stems per acre with Ammate or 2,4-D (80), $2.40 per acre to kill low-value hardwoods in the South (13), $13 to $44 (average $30) per acre for spraying power-line rights-of-way (67), and $6 to $9 for foliage sprays (27).

Ammate, despite its low price per pound, has cost from $35 to $50 for foliage spraying of brush in the Northeast where several hundred gallons of solution had to be applied per acre (36, 45). In contrast, it cost $13 per acre to apply 2,4,5-T to alder (71). In this same test, better control of the alder was obtained by swabbing cut stumps with a solution of Ammate, with a cost of $25 per acre. However, the results from the cheaper spraying of 2,4,5-T were deemed adequate to accomplish the objective of releasing understory conifers. Foliage spraying with hormone-type sprays is undoubtedly the most effective and cheapest method of brush control along roads or other rights-of-way easily accessible to motor vehicles. Tests along a telephone right-of-way cost $39.10 for hand cutting of the 8-year-old northern hardwood and aspen brush, compared to $16.20 for 2,4,5-T spraying with back-pack fire pumps, and $35.40 with power equipment (69). The power equipment and its methods of use were wasteful of the chemical, accounting for the unusually high cost. For application of herbicides to larger blocks of land, the use of airplanes is by far the cheapest. Costs of airplane spraying of 2,4-D or 2,4,5-T ranged from $2.50 (76) to $3.50 per acre (59) when applying from 2.5 to 5 gallons per acre. Application with helicopters has cost from $3 to $4 for 10 gallons of spray per acre (25).

Basal spraying of herbicides requires comparatively large amounts of oil solution of the herbicides to insure thorough wetting of the base of the tree to the point of runoff and is not generally recommended for trees over 4 inches in diameter on the stump (9).

One series of tests showed the following use of herbicide sprays per inch of diameter of the treated trees: Basal spraying of 3- to 10-inch trees, 72 milliliters; Cornell tool treatment of 3- to 10-inch trees, 4.5 milliliters; Cornell tool treatment of 10- to 30-inch trees, 4.7 milliliters; and frill girdling of 10- to 20-inch trees, 27 milliliters (40). When considering both the labor time and material costs, the Cornell tool application was the cheapest, the basal spraying the most expensive, and the frill girdling intermediate in cost. The large amount of spray required for basal spraying made this method the most expensive even though the labor requirements were the least.

In a test (9) of four methods of control--cutting small trees with an axe and felling larger ones, poisoning with Ammate on cut stumps or in notches, and basal spraying to two heights, 2 and 4 feet--basal spraying required the least amount of labor; poisoning with Ammate gave the highest labor requirements. With known local costs of labor and chemicals, information from this test can be used to determine total costs of the four methods of control.

In another test in Lower Michigan, chemical frill girdling with a crew of 4 (3 axemen and 1 man to apply the chemical), 1,000 inches of diameter were treated per hour with about 1.5 gallons of herbicide solution (8). The spray, 4 pounds a.h.g. of 2,4,5-T in oil, gave good top-kill; one-half to one-third of the treated trees sprouted, depending upon the season of treatment.

A test in the South on hardwood control showed that frill girdling cost $3.60 per acre compared to $8.38 per acre for poisoning with Ammate in notches on large trees and on cut stumps of small ones (37). However, if sprouting is a problem, the more expensive treatment is considered the more desirable because of the much smaller number of sprouts produced.

Notching with Ammate in the Lake States costs $2.49 per 100 trees (70). A formula developed for estimating the cost of deadening trees with Ammate by notching the larger trees and felling and treating the cut stumps of smaller trees is: Man-hours = 0.009 x sum of diameters - 0.005 x number of trees per acre (44). About 4 pounds of Ammate were used for every 100 inches of diameter treated. For smaller trees, largely under 5 inches d.b.h., one-third of the basal area to be treated will be the number of man-hours required; $1\frac{1}{2}$ to 2 pounds of Ammate will be required for each square foot of basal area.

A test with Ammate solution injected with the Cornell tool gave costs not much in excess of conventional cutting methods (68).

Another test in the South, using water emulsion of 2,4,5-T in frills, required 2.32 man-hours and 1.60 gallons of spray at 25 cents per gallon to kill 70 trees per acre with an average diameter of 7.6 inches (14).

In estimating the cost of brush control, it usually is not necessary to plan for complete kill of existing vegetation. But such vegetation must be killed back sufficiently to enable the desired tree species to dominate any sprouts that follow top-killing of the brush. In some cases, a more complete kill will result in the establishment of grasses and other herbaceous plants that may offer more competition than the brush present before treatment.

Of course, sometimes, as on rights-of-way, a complete kill is often desirable; the cost of several treatments to remove species that are strong sprouters will then have to be computed. Selective spraying to encourage a stand of low-growing species has been advocated as a means of establishing a right-of-way cover that will maintain itself for long periods (29). Stable communities of brush or herbaceous plants have been observed. If such communities can be established by spraying, the frequency of respraying may be reduced greatly. Generally, shrubs seem to hold the most promise of maintaining themselves without invasion of tree species, at least in the Northeast. The success of such operations hinges upon better knowledge of what species constitute stable communities on different sites.

The examples above indicate the range of costs encountered in various methods of brush control. Treatment costs will vary with the particular conditions encountered and the efficiency of the workers. As with any management job in forestry, each potential brush control operation will have to be inspected and the means available for treatment weighed in the light of the knowledge of methods used in the past, the equipment available for the job, and the purpose of the work.

METHODS SUGGESTED FOR THE LAKE STATES

In the preceding sections present knowledge of chemical control of woody plants applicable in the Lake States has been summarized. Based on this information, what appear to be the most useful methods under various conditions are presented briefly in the following pages. Results of various tests for Lake States woody plants are given in tabular form in the Appendix. Also in the Appendix are listings of suppliers of herbicides and spray equipment.

When planning a chemical treatment, it should be remembered that complete kills have seldom been obtained with one operation. In some instances, a single treatment may be all that is needed. This is especially true in operations designed to release desirable tree growth, in which case killing overtopping brush at the right time is sufficient to allow the trees to gain ascendancy over the brush, even though it may sprout after top-killing. In other cases, such as control along rights-of-way, followup sprays will be needed at intervals. In any spray operation, results should not be evaluated until at least 1 and preferably 2 or 3 full growing seasons after treatment during which both sprouting and mortality may occur.

TO CONTROL BRUSH ON ROADSIDES, RIGHTS-OF-WAY, AND FIRELINES

On roadsides, rights-of-way, and firelines, where complete brush kill along narrow strips is desired, use a foliage spray of 2,4,5-T in low-volatile ester formulations, applied soon after the leaves are fully expanded. Concentrations of about 2 pounds a.h.g. are sufficient. Brushkillers--mixtures of 2,4-D and 2,4,5-T esters--

may be used, but the straight 2,4,5-T spray will probably be somewhat more effective on mixed brush. If the brush is of species susceptible to 2,4-D, use of this chemical alone will reduce the cost of spray material. When the brush is continuous, use a power sprayer mounted on a vehicle with spray booms. If only occasional clumps of brush are encountered, either a knapsack sprayer or a power sprayer with several hoses terminated with trigger-type valves at the nozzles may be used. Leaves and young stems should be covered with the spray.

If aesthetic considerations are important, as in recreational areas, cutting the brush before chemical treatment is desirable, although more expensive. 2,4,5-T at about 12 pounds a.h.g. in oil should be used to wet thoroughly the cut surface, sides, and base of the stumps. High stumps are easier to cut and treat, but may interfere with access along the right-of-way. Addition of a dye to the spray will aid in identifying treated stumps. An alternative to this treatment would be to mow the brush in midsummer with power equipment and then the following summer apply a foliage spray to the resultant sprouts at the full-leaf stage. This would, of course, reduce the cost of herbicides and probably of the total operation. Ammate solution at about 6 pounds per gallon of water may also be used as a spray on the cut surface.

In the Alleghenies, basal spraying without first cutting the brush gave better control than foliage spraying and permitted selection of plants to be left untreated. Therefore, although this treatment was as much as 3 times as costly as foliage spraying, it was considered more desirable (72). 2,4,5-T at 12 pounds a.h.g. in oil is effective in this sort of treatment.

The initial application of herbicides is much more costly than second and later applications. Information is not available on the frequency of respraying needs; much will depend upon the species of brush, the site, the type of control desired, and the efficiency of the original application. In any case, respraying should not be attempted until the sprout growth has resumed its normal habits of growth. Distorted sprouts, which often are found soon after treatment, are not easily injured by respraying (18). After 2 or 3 treatments, the costs and frequency of treatments should be very low.

TO RELEASE LARGE CONIFEROUS PLANTATIONS

To release large coniferous plantations overtopped by broadleaf shrubs or trees, use an ester formulation of 2,4,5-T. About 1 to 2 pounds of acid in 3 to 5 gallons of oil emulsion spray per acre in aerial applications will give good results with most species. If the brush is susceptible to it, 2,4-D is satisfactory; otherwise, the less selective 2,4,5-T will be more desirable although more expensive per pound.

Spraying should be attempted only after the conifers harden off. Northern Minnesota experience indicates that spraying to release the spruces can begin about July 10 to 15, red pine after July 20. A Lower Michigan test showed that white spruce can be safely sprayed after July 15; all other species can be sprayed by August 1, although some browning occurred on jack pine until August 15 (7). Variation in weather conditions may change the date of earliest spraying from year to year. The slight damage caused to the conifers will not affect their growth noticeably; however, needle drooping, which is sometimes conspicuous in red pine, would make such treatment inadvisable on Christmas tree plantations. One treatment may give the brush enough of a setback to permit the conifers to outgrow it; in some instances, additional treatments may be needed.

Small fixed-wing aircraft that can land on small fields located close to the area to be sprayed are more economical and maneuverable than planes with larger capacity. If desirable, they may be equipped to land on nearby lakes.

Ground spraying of plantations has been made obsolete by aerial spraying, except for those that are too small to be economically sprayed from the air or are so located that damage to crops prohibits the use of aerial spraying. In such cases, power equipment mounted on vehicles or, for small areas, knapsack sprayers may be used.

TO PREPARE BRUSHY AREAS FOR PLANTING

To prepare brushy areas for planting, aerial application of herbicide sprays similar in volume and concentration to that used for plantation release should be made during the growing season. Preplanting release can be done earlier in the season than plantation release because there is no need to delay spraying until the conifers have hardened off. Thus, the brush can be sprayed at the full-leaf stage when the treatment is most effective. After the brush is killed, burning, if possible, would clear the areas of dead stems for more ready access by planting crews.

In most cases, the sprouts will have to be controlled with additional spraying several years after establishment of the plantation. Fourth-year results of growth and survival of red pine showed that 42 percent of the trees on the sprayed area needed release compared to 71 percent on the untreated planting site. Other advantages gained by the spraying were slightly better survival, nearly twice the height growth, and a 70-percent reduction in hare damage (65).

Aerial spraying appears to have a great advantage over disking in preparation of brushy areas for planting. In northern Minnesota, such spraying can be done for about one-fourth the cost of disking;

sprayed areas should require no more subsequent release than disked ones. Planting sites that are too stony or rough or are inaccessible to disking equipment can be sprayed aerially to permit successful and economical planting. Another advantage is that sprayed areas can be planted with machines, an impossibility on disked land where the surface is left in rough condition.

TO REMOVE BRUSH UNDER MATURE PINE

Herbicides may be used to reduce the competition of brush with reproduction already present or expected under stands of mature pine. 2,4-D or 2,4,5-T, depending upon the brush species present, may be used as a foliage spray applied by knapsack sprayer if the brush is scattered or by jeep- or tractor-mounted equipment if the brush is continuous. A recent test in northern Minnesota showed that aerial sprays also may be used; the spray penetrated the overstory pine, giving good control of the brush without harming the pine. Spraying should be delayed until the pine hardens off to avoid injury to any existing reproduction. Spraying of moderately dense hazel brush under a mature stand of red and white pines resulted in 24 to 160 percent more seedlings than before treatment compared to a gain of 2 percent on the untreated plots. Only 21 percent of the seedlings on the plots sprayed with 2,4-D in June, the most effective treatment, needed release 7 years after treatment compared to 58 percent on the check plots (63).

TO REMOVE INDIVIDUAL STEMS

To remove individual stems of nonmerchantable or undesirable trees, a number of methods can be used. Frilling (making a series of overlapping cuts through the bark and into the wood with an axe) and applying 4 pounds a.h.g. oil solutions of 2,4,5-T ester is usually the most economical method of chemical treatment to remove individual trees larger than 4 inches. Good control of sprouting is also obtained. Summer and fall treatments gave the best control of sprouts with 2,4,5-T in the Lake States; the lower the location of the frill, the better the control of sprouting (8). Notching every 6 inches of circumference and placing a tablespoonful ($\frac{1}{2}$ ounce) of Ammate crystals in each notch also gives good results. Small trees that are easily severed with a few strokes of the axe should be cut, and the crystals placed on the cut surface. Basal spraying of individual trees with 4 pounds a.h.g. of 2,4,5-T also is effective, but the lower foot or so of the tree must be sprayed to the point of runoff with oil solutions. This requires considerably more chemical than the frilling described and, therefore, cannot be recommended for larger trees.

MORE RESEARCH NEEDED

Chemical control of woody plants has become an accepted practice. Research in this field has come a long way in the past few years. As the power saw has replaced the crosscut saw in felling trees, so the spray gun has replaced the mower, brush hook, and other cutting tools in brush control. But there is still much to be learned.

Basic information is needed to explain seemingly contradictory results obtained in some past tests. These may be due to subtle but important differences in application or physiological condition of the plants. For example, some workers report good kill of aspen with hormone herbicides; others have little success. What causes the difference?

Season of application has still to be investigated thoroughly. For example, when in the fall should foliage spraying be discontinued?

We are discovering that we know comparatively little about the ecology of our various troublesome brush species. How do they invade areas? What is the extent of interconnection between nearby plants of a given species? What are their growth rates on various sites? How can we establish permanent stands of desirable brush in the face of competition with other species?

These are but some of the problems awaiting solution by researchers. This Station and other organizations in the region are actively engaged in trying to find the answers. And as our knowledge is increased and new chemicals and methods of application are developed, our control work will gain in effectiveness and economy.

LITERATURE CITED[4/]

(1) Anonymous.
1950. Progress with dormant brush control. Down to Earth 5(4): 8.

(2) Ahlgren, Clifford E., and Stewart, Donald M.
1952. Chemical eradication of ribes by herbicides. Quetico-Superior Wilderness Res. Center Tech. Note 1, 4 pp. (Processed.)

(3) Arend, John L.
1951. Can hardwood roots transmit chemical herbicides? Forest Farmer 11(1): 15.

(4) ______
1952. Oil versus water carriers with 2,4,5-T applied to frill girdles. (Abstract.) No. Cent. Weed Control Conf., 9th Ann. Res. Report, p. 52. (Processed.)

(5) ______
1953. Scrub aspen control with basal sprays. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 401, 1 p. (Processed.)

(6) ______
1954. Chemical herbicides as tools in forest management. Soc. Amer. Foresters Proc. 1954: 194-198.

(7) ______
1955. Tolerance of conifers to foliage sprays of 2,4-D and 2,4,5-T in Lower Michigan. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 437, 2 pp. (Processed.)

(8) ______
1955. Chemical frill girdling in summer and fall gives best results in Lower Michigan. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 438, 1 p. (Processed.)

4/ Includes a number of abstracts from the Annual Research Reports of the North Central Weed Control Conference. These abstracts are largely reports on preliminary work, and the results cannot be considered as final. However, they were included to bring the reader abreast of current work.

(9) ______ and Stephenson, Joseph R.
1952. Some costs and effects of chemical release of pine in northern Michigan. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 367, 1 p. (Processed.)

(10) Ashbaugh, F. A.
1950. Chemical right-of-way brush control has grown up. Down to Earth 6(3): 2-4, illus.

(11) Campbell, R. S., and Peevy, Fred A.
1950. Chemical control of undesirable southern hardwoods. Jour. Range Mangt. 3(2): 118-124, illus.

(12) Carvell, Kenneth L.
1955. Translocation of Ammate. Forest Sci. 1: 41-43, illus.

(13) Cassaday, John T., and Peevy, Fred A.
1948. From scrubby hardwoods to merchantable pine. South. Lumberman, pp. 115-118, illus. Dec. 15.

(14) Chaiken, L. E.
1951. Tree poisoning with 2,4,5-T in frills. The Tree Farmer 10(9): 9, 12, illus.

(15) Cook, David B.
1953. A simple device for applying Esteron 245. Down to Earth 9(3): 5, illus.

(16) Coulter, L. L.
1950. Herbicidal action of chemicals in weed and sprout control. Weed and Sprout Control Short Course and Conf. Proc., Prog. Rept. 9, pp. 4-6. (Mo. Agr. Expt. Sta.)

(17) ______
1954. Silvex, a new selective herbicide. Down to Earth 9(4): 18-19, illus.

(18) ______
1954. Some aspects of right-of-way brush control with 2,4,5-T and 2,4-D. Weeds 3(1): 21-27.

(19) Crafts, A. S., and Harvey, W. A.
1950. Chemical structure and action of herbicides. Agr. Chem. 5(3): 38-41, 89.

(20) Dahms, Walter G., and James, George A.
1955. Brush control on forest lands, with emphasis on promising methods for the Pacific Northwest. (A review of selected references.) U. S. Forest Serv., Pac. Northwest Forest and Range Expt. Sta. Res. Paper 13, 81 pp. (Processed.)

(21) Day, Maurice W.
1947. The use of dinitro phenol for the control of aspen. Quart. Bul. Mich. Agr. Expt. Sta. 30: 241-243.

(22) ______
1948. The chemical control of certain forest shrubs. A progress report. Quart. Bul. Mich. Agr. Expt. Sta. 30: 427-436.

(23) ______
1952. A frill girdle treatment for aspen. (Abstract.) No. Cent. Weed Control Conf., 9th Ann. Res. Report, p. 54. (Processed.)

(24) ______
1954. Foliage sprays for maple sprout clumps. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Report, p. 131. (Processed.)

(25) DeJarnette, G. M.
1953. Tests of helicopter spraying for eradication of ribes. Northwest Sci. 27: 107-113.

(26) ______ and Augenstein, J. W.
1950. Annual planting and nursery report, fiscal year 1950, U. S. Forest Serv., Region One, pp. 4-5. (Processed.)

(27) Dingle, Richard William.
1950. The use of chemicals for the elimination of low-value species as a forest improvement measure. Weed and Sprout Control Short Course and Conf. Proc., Prog. Rept. 9, pp. 29-32. (Mo. Agr. Expt. Sta.)

(28) Drake, C. R., and Kuntz, J. E.
1954. Eradication of scrub oak to prevent the local spread of oak wilt. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Rept., p. 131. (Processed.)

(29) Egler, Frank E.
1954. Vegetation management for right-of-ways and roadsides. Smithsonian Inst. Rept. for 1953: 299-322. Pub. 4157. illus.

(30) Grigsby, Buford H.
1951. Effects of herbicides on hydrocyanic acid content of *Prunus serotina* Ehrh. leaves. (Abstract.) No. Cent. Weed Control Conf., 8th Ann. Res. Rept., pp. 178-179. (Processed.)

(31) ______ and Farwell, E. D.
1950. Some effects of herbicides on pasture and on grazing livestock. Mich. Agr. Expt. Sta. Quart. Bul. 32: 378-385.

(32) Hackett, David.
1952. Experiments on the chemical control of hardwoods in northeastern forests. 6th Ann. Meeting Northeast. Weed Control Conf. Proc.: 311-319. (Processed.)

(33) Hansen, H. L.
1954. Tests of MCP, 2,4-D, and 2,4,5-T on prickly ash (Xanthoxylum americanum) in Minnesota. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Rept., pp. 131-132. (Processed.)

(34) ______ and Loerch, Karl A.
1950. The effect of sodium trichloroacetate on the germination and survival of red pine seedlings. (Abstract.) No. Cent. Weed Control Conf., 7th Ann. Res. Rept., pp. 238-239.

(35) Herman, Francis R.
1949. Use of "ammate" for poisoning ponderosa pine in stand improvement. Jour. Forestry 47: 966-967.

(36) Hough, A. F.
1950. Weed killers may be useful in reforesting old burns. U. S. Forest Serv., Northeast. Forest Expt. Sta. Res. Note 1, 4 pp. (Processed.)

(37) Huckenpahler, B. J.
1952. Axe or poison? South. Lumberman 185(2321): 180-182, illus.

(38) Ikenberry, G. I., Bruce, H. D., and Curry, John R.
1938. Experiments with chemicals in killing vegetation on firebreaks. Jour. Forestry 36: 507-515.

(39) Jacobs, Homer L.
1950. Clearing woody plants from right-of-ways. Weed and Sprout Control Short Course and Conf. Proc., Prog. Rept. 9, pp. 14-18. (Mo. Agr. Expt. Sta.)

(40) Jokela, J. J., and Lorenz, Ralph W.
1955. Comparison of three methods of eliminating cull trees from woodlands with 2,4,5-T. Jour. Forestry 53: 901-904.

(41) Kephart, L. W.
1950. Chemicals used in weed killing. U. S. Dept. Agr. Bur. Plant Indus., Soils, & Agr. Engin., No. 82CC, 7 pp. (Processed.)

(42) Kuntz, J. E., and Riker, A. J.
1950. The translocation of poisons between oak trees through natural root grafts. (Abstract.) No. Cent. Weed Control Conf., 7th Ann. Res. Rept., p. 242.

(43) Larson, Philip R., Loerch, Karl A., and Hansen, Henry L.
1952. The tolerance of several tree species to TCA used in controlling quack grass (Agropyron repens (L) Beauv.) in nurseries. Univ. Minn. Forestry Note 6, 2 pp. (Processed.)

(44) McClay, T. A.
1953. Estimating time requirements for tree poisoning with ammate. Jour. Forestry 51: 909.

(45) McQuilkin, W. E.
1951. Weed killers of limited use in reforesting scrub oak barrens. U. S. Forest Serv., Northeast. Forest Expt. Sta. Res. Note 6, 4 pp. (Processed.)

(46) ______
1955. Use ammate in notches for deadening trees only during the growing season. U. S. Forest Serv., Northeast. Forest Expt. Sta. Res. Note 52, 2 pp. (Processed.)

(47) Melander, L. W.
1955. Effect of Amizol (3-amino-1,2,4,-triazole) on buck-brush (Symphoricarpos occidentalis). (Abstract.) No. Cent. Weed Control Conf., 12th Ann. Res. Rept., p. 161. (Processed.)

(48) ______
1955. Effect of Amizol (3-amino-1,2,4-triazole) on poison ivy (Rhus radicans). (Abstract.) No. Cent. Weed Control Conf., 12th Ann. Res. Rept., p. 165. (Processed.)

(49) ______, Campbell, Mac, and Watson, Wm.
1951. Herbicidal effect of MCP on European and Allegheny bar-berry. (Abstract.) No. Cent. Weed Control Conf., 8th Ann. Res. Rept., p. 158. (Processed.)

(50) Meyers, W. A.
1954. The effectiveness of Amizol on mixed brush. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Rept., p. 128. (Processed.)

(51) ______, Turner, M. B., and Pintcke, I.
1955. Comparison of 2,4-D propionic, 2,4,5-T propionic, MCP propionic, and 2,4,5-T acetic on mixed brush. (Abstract.) No. Cent. Weed Control Conf., 12th Ann. Res. Rept., p. 164. (Processed.)

(52) Moss, V. D., and Offord, H. R.
1950. Killing brush with chemicals in the western white pine region. U. S. Dept. Agr. Bur. Ent. & Plant Quar., Blister Rust Control, 7 pp. (Processed.)

(53) Mullison, Wendell R.
1951. The relative herbicidal effectiveness of several derivatives of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid. Plant Physiol. 26: 773-777.

(54) Nichols, J. M.
1952. Basal bark and frill treatment of pole-size post oak and hickory. (Abstract.) No. Cent. Weed Control Conf., 9th Ann. Res. Rept., p. 60. (Processed.)

(55) Offord, H. R., et al.
1952. Improvement in the control of ribes by chemical and mechanical means. U. S. Dept. Agr. Cir. 906, 72 pp., illus.

(56) Pavlychenko, T. K., and Bestrop, A. J.
1953. Foliage treatments of buckbrush, rose, and chokecherry, 1952-1953. (Abstract.) No. Cent. Weed Control Conf., 10th Ann. Res. Rept., p. 61. (Processed.)

(57) Playfair, Lloyd.
1955. 2,3,6-trichlorobenzoic acid as a foliage spray. (Abstract.) No. Cent. Weed Control Conf., 12th Ann. Res. Rept., p. 165. (Processed.)

(58) Quaite, J.
1953. Poisoning with "ammate" to eliminate aspen. Canada Dept. North. Affairs and Natl. Resources, Forestry Branch Silv. Leaflet 94, 2 pp.

(59) Ralston, R. A., and Coulter, L. L.
1954. Aerial spray tests with 2,4,5-T for scrub oak control in Lower Michigan. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 424, 1 p. (Processed.)

(60) Read, R. A.
1950. Relation between time of treatment and sprouting of poisoned trees. Sci. 111: 264.

(61) Roe, E. I.
1951. Effect of time of spraying with 2,4-D and 2,4,5-T on resprouting of hazel. (Abstract.) No. Cent. Weed Control Conf., 8th Ann. Res. Rept., p. 162. (Processed.)

(62) ______
1953. Resprouting of mountain maple after basal spraying with 2,4,5-T. (Abstract.) No. Cent. Weed Control Conf., 10th Ann. Res. Rept., pp. 73-74. (Processed.)

(63) ______
1954. Spraying hazel with herbicides aids establishment and growth of pine reproduction. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Rept., pp. 135-136. (Processed.)

(64) ______
1954. Aerial spraying to release planted spruce from overtopping hardwood. (Abstract.) No. Cent. Weed Control Conf., 11th Ann. Res. Rept., p. 136. (Processed.)

(65) ______
1955. Forest plantation release. What it is--How to do it. U. S. Forest Serv., Lake States Forest Expt. Sta. Misc. Rept. 33, 29 pp., illus. (Processed.)

(66) ______
1955. Aerial brush control in Lake States forests. U. S. Forest Serv., Lake States Forest Expt. Sta. Misc. Rept. 37, 9 pp. (Processed.)

(67) Rural Electrification Administration.
1949. Interim report on chemical control of right-of-way brush on rural power systems. U. S. Dept. Agr. (No Series), 20 pp. (Processed.)

(68) Shipman, R. D.
1953. Poisoning small diameter hardwoods with the Cornell tool. U. S. Forest Serv., Southeast. Forest Expt. Sta. Res. Note 38, 2 pp. (Processed.)

(69) Stoeckeler, J. H.
1951. Chemical sprays reduce right-of-way maintenance costs. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 359, 1 p. (Processed.)

(70) ______ and Dosen, Robert C.
1951. Scrub oak control in central Wisconsin by use of ammonium sulfamate. (Abstract.) No. Cent. Weed Control Conf., 8th Ann. Res. Rept., p. 163. (Processed.)

(71) ______ and Heinselman, M. L.
1950. The use of herbicides for the control of alder brush and other swamp shrubs in the Lake States. Jour. Forestry 48: 870-874.

(72) Strickenberg, L. R., and McQuilkin, W. E.
1955. Report of tests of brush control by chemicals in Region 7, 1954. U. S. Forest Serv., 24 pp., illus. (Processed.)

(73) Swain, L. C.
1954. Economical tree killing. Univ. N. H. Agr. Expt. Sta. Bul. 408, 15 pp., illus.

(74) Wasicky, Richard, and Hoehne, Wilson.
1948-1949. Contribuicao para o estudo do mecanismo da seletividade herbicida de 2,4-D, acido diclorofenoxiacetico. (The mechanism of action of 2,4-D.) (Abstract.) Anais Fac. Farm. e Odont. Univ. Sao Paulo 7: 417-422.

(75) Westing, Arthur H.
1955. Effects of undiluted 2,4-D and 2,4,5-T in cut surfaces on oak in Lower Michigan. (Abstract.) No. Cent. Weed Control Conf., 12th Ann. Res. Rept., p. 168. (Processed.)

(76) Wiksten, Ake.
1955. Chemical brush control experiments, 1951-1955. A progress report. Weyerhaeuser Timber Co. Forestry Res. Note, 21 pp. illus.

(77) Woods, Frank W.
1955. Tests of CMU for forestry. Forest Sci. 1: 240-243.

(78) ______
1955. Control of woody weeds, some physiological aspects. U. S. Forest Serv., South. Forest Expt. Sta. Occas. Paper 143, 50 pp. (Processed.)

(79) Wyman, Donald.
1950. Killing woody plants with chemicals. Arnoldia 10 (10-11): 61-71.

(80) Zehngraff, Paul, and von Bargen, John.
1949. Chemical brush control in forest management. Jour. Forestry 47: 110-112.

APPENDIX

Table A.--Chemical control methods for Lake States woody plants[1]

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Ailanthus	Ailanthus altissima	2,4,5-T	16 lbs ahg (oil)	BS	D	
		Comb. esters	16 lbs ahg (oil)	BS	D	
Alder, speckled	Alnus incana	2,4-D	1100-3300 ppm	FS	YS,E	M,MH,L
		2,4,5-T	1000-2000 ppm	FS	YS,M	E,M,MH
		2,4,5-T	4000-5000 ppm (oil)	BS	M	D
		Comb. esters[8]	8000 ppm	FS	M,MH	
		" "	8000 ppm	CS	MH	
		" "	10,000 ppm (oil)	BS	M	
		Ammate	50-200 lbs/A	FS		M,MH
		"	3/4-1 lb/gal	FS		M
		"	4 lbs/gal	FS	MH	
		"	4 lbs/gal	CS		M
		"	2 lbs/gal	CS	M	
		DNOSP[9]	.05 lbs/gal (oil)	BS	M	
Alder, green	Alnus crispa	2,4-D	2400 ppm	FS		M
		2,4,5-T	2400 ppm	FS		M
Apple, American crab	Malus coronaria	2,4-D	3000 ppm	FS	YS	E,M,MH
		Comb. esters	3000 ppm	FS	YS,E,M,MH	L
Apple, prairie crab	Malus ioensis	Comb. esters	2 lbs/A	CS	D	

See footnotes at end of table.

Species name		Herbicide[2/]	Concentration or rate[3/]	Kind of application[4/]	Season at which obtained[5/]	
Common	Scientific				Good control[6/]	Fair control[7/]
Ash, green	Fraxinus pennsylvanica	Comb. esters	4000-6000 ppm	FS	E,M	MH
		Ammate	3/4 lb/gal	FS	M	
Ash, white	Fraxinus americana	2,4,5-T	11 lbs/A (emulsion)	BS	D	
		Aminotriazole	6 lbs ahg	FS	M	D
Aspen, bigtooth	Populus grandidentata	2,4-D	8 lbs ahg (oil)	BS	All seasons	
		2,4-D	8000 ppm (oil)	BS	D,E,M,MH	
		2,4-D	6000 ppm (oil)	BS	E,M,MH	
		2,4,5-T	4-8 lbs ahg (oil)	BS	All seasons	
		2,4,5-T	4 lbs ahg (oil)	AX (frill)	All seasons	
		Ammate	3/4-1 lb/gal	FS		M
		DNOSP	.05 lb/gal (oil)	BS	M	
Aspen, quaking	Populus tremuloides	2,4-D	1100-3300 ppm	FS		YS,E,M,MH
		2,4-D	8000 ppm (oil)	BS	D,MH	M
		2,4-D	1.5% (oil)	BS	D	
		2,4,5-T	1000-2000 ppm	FS	M	
		2,4,5-T	1 lb/A (emulsion)	FS (aerial)	-	M
		2,4,5-T	8000 ppm (oil)	BS	D,M,MH	
		2,4,5-T	8-16 lbs ahg (oil)	BS	All seasons	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		Comb. esters	3000 ppm	FS	YS,E,M	MH,L
		" "	1.8 lbs/A	FS	M	
		" "	1.5% (oil)	BS	D	
		Ammate	50-200 lbs/A	FS		M,MH
		"	3/4-1 lb/gal	FS,AX	YS	M
		DNOSP	.05 lb/gal (oil)	BS	M	

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Bearberry	Arctostaphylos uva-ursi	2,4-D	3000 ppm	FS	M	
		Comb. esters	3000 ppm	FS	M	
Beech, American	Fagus grandifolia	2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
Birch, paper	Betula papyrifera	2,4-D	2000-3000 ppm	FS		E,M,MH,L
		2,4-D	1 lb/A (emulsion)	FS (aerial)	MH	
		2,4,5-T	1000-2000 ppm	FS		E,M,MH
		2,4,5-T	1 lb/A (emulsion)	FS (aerial)	MH	
Birch, river	Betula nigra	2,4-D	10,000 ppm	FS	M	
		2,4,5-T	10,000 ppm	FS	M	
Blackberry	Rubus spp.	2,4,5-T	2000 ppm	FS	YS,E,M,MH,L	
		2,4,5-T	8000 ppm (oil)	BS	D	
		Comb. esters	1000-6000 ppm	FS	YS,E,M,MH	
		Ammate	3/4 lb/gal	FS	M	
Blueberry, low-bush	Vaccinium angustifolium	2,4-D	2000 ppm	FS		E,MH
		Ammate	2-4 lbs/gal	FS	M,MH	
Blueberry, smoothleaf	Vaccinium angustifolium var. laevifolium	2,4-D	38,400 ppm	FS		M
		2,4,5-T	19,200 ppm	FS		M
		Comb. esters	9,600 ppm	FS		M
Boxelder	Acer negundo	2,4-D	3000 ppm	FS		YS,E,M,MH
		2,4-D	25 lbs ahg (oil)	AX	D	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		Comb. esters	2000-3000 ppm	FS		YS,E,M,MH
		" "	15 lbs ahg (oil)	AX	D	

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Bracken	Pteridium aquilinum	Ammate	2-4 lbs/gal	FS	M,MH	
Buckthorn	Rhamnus cathartica	Comb. esters	2% (oil)	BS	E,M	
Butternut	Juglans cinerea	2,4-D	3000 ppm	FS	YS	E,M
		Comb. esters	3000 ppm	FS	YS	E,M,MH,L
Bushhoneysuckle, dwarf	Diervilla lonicera	2,4-D	2400 ppm	FS		M
		2,4,5-T	2400 ppm	FS		M
		Comb. esters	2400 ppm	FS		M
		Ammate	1 lb/gal	FS	MH	
Cherry, black	Prunus serotina	2,4-D	3000 ppm	FS	YS,E,M,MH	L
		2,4-DP	4 lbs ahg	FS	M	
		2,4,5-T	1500-2000 ppm	FS	YS,E,M,MH	L
		2,4,5-T	4 lbs ahg	FS	M	
		Comb. esters	3000 ppm	FS	YS,E,M,MH,L	
		MCP	4 lbs ahg	FS	M	
		Aminotriazole	6 lbs ahg	FS	M	
		"	4 lbs ahg	FS		M
		Ammate	1 lb/gal	FS	YS,M	

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Cherry, Choke	Prunus virginiana	2,4-D	2000 ppm	FS		YS,E,M,MH
		2,4-D	4000 ppm (oil)	BS		D
		2,4,5-T	4000 ppm	FS	M,MH	
		Comb. esters	3000 ppm	FS	YS,E,M,MH,L	
		Ammate	1 lb/gal	FS	M	
Cherry, pin	Prunus pensylvanica	2,4,5-T	1000-2000 ppm	FS	M,MH	
		2,4,5-T	5000 ppm (oil)	BS	D	
		Comb. esters	3000 ppm	FS	YS,E,M,MH,L	
		Ammate	3/4-1 lb/gal	FS	M,MH	
Chokeberry	Aronia spp.	Ammate	2-4 lbs/gal	FS	M,MH	
Coralberry, Indian-currant	Symphoricarpos orbiculatus	2,4-D	2000 ppm	FS	YS,E,M,MH	
		Comb. esters	6000 ppm	FS	YS,E,M,MH	
Cottonwood, eastern	Populus deltoides	2,4-D	3000 ppm	FS	YS	E,M,MH,L
		2,4-D	25 lbs ahg	AX	D	
		Comb. esters	1000-3000 ppm	FS		E,M,MH
		" "	4000 ppm	FS	YS,M,MH	
		Ammate	2 lbs/stump	CS	E	
Cranberry, small	Vaccinium oxycoccus	2,4-D	9600 ppm	FS		M
		2,4,5-T	9600 ppm	FS		M
		Comb. esters	4800 ppm	FS		M

See footnotes at end of table.

Species name		Herbicide [2]	Concentration or rate [3]	Kind of application [4]	Season at which obtained [5]	
Common	Scientific				Good control [6]	Fair control [7]
Creeper, Virginia	Parthenocissus quinquefolia	2,4-D	1000-2000 ppm	FS		YS,E,M
		2,4-D	1000-2000 ppm	CS	D	
		Comb. esters	3000 ppm	FS		YS,E,M,MH,L
Currant, American black	Ribes americanum	2,4-D salts and esters	1000 ppm	FS	YS,E,M,MH,L	
		2,4,5-T	1000 ppm	FS	YS,E,M,MH,L	
		2,4,5-T	24,000 ppm	BS	E,M,MH,L	
		Comb. esters	1000 ppm	FS	YS,E,M,MH,L	
Currant, swamp black	Ribes lacustre	2,4,5-T	2000 ppm	FS,CS	YS,E,M,MH,L	
Currant, swamp red	Ribes triste	2,4,5-T	6000 ppm	FS		YS,E
		2,4,5-T	12,000 ppm	FS	E	
		Comb. esters	6000 ppm	FS		YS,E
Dewberry, northern	Rubus flagellaris	Comb. esters	3000 ppm	FS		YS
Dogwood, red-osier	Cornus stolonifera	2,4-D	1-2 lbs/A	FS		M
		Comb. esters	3000-6000 ppm	FS		E,M,MH
		2,4,5-T	4000 ppm	FS		M
Dogwood, roundleaf	Cornus rugosa	2,4-D	2400 ppm	FS		M
		2,4,5-T	2400 ppm	FS		M
		Comb. esters	2400 ppm	FS		M

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Elder, American	Sambucus canadensis	2,4-D	3000 ppm	FS	YS,E,M	MH,L
		2,4,5-T	2000 ppm	FS		M
		Comb. esters	1000-8000 ppm	FS	YS,E,M	L
		Ammate	3/4 lb/gal	FS	M	
Elm, American	Ulmus americana	2,4-D	3000 ppm	FS	YS,E,M,MH	L
		2,4-D amine	Undiluted commercial	AX	D	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4,5-T	1500 ppm	FS	YS,E,M	MH,L
		Comb. esters	8 lbs ahg (oil)	BS	D	
		" "	3000 ppm	FS	YS,E,M,MH	L
		Ammate	3/4 lb/gal	FS	M	
Elm, slippery	Ulmus rubra	2,4-D amine	Undiluted commercial	AX	D	
		Comb. esters	4000-6000 ppm	FS	E,M,MH	
Elm, Siberian (Chinese)	Ulmus pumila	2,4-D salts and esters	1000 ppm	FS		YS
		2,4-D	96,000 ppm	CS		E,M
Gooseberry, Missouri	Ribes missouriense	2,4,5-T	6000 ppm	FS	YS	E,M
		Comb. esters	6000 ppm	FS	YS	E,M
Gooseberry, prickly	Ribes cynosbati	2,4,5-T	6000 ppm	FS	YS	E,M
		2,4,5-T	24,000 ppm (oil)	BS	E,M	MH,L
		Comb. esters	6000 ppm	FS	YS	E,M

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Gooseberry, hairystem	Ribes hirtellum	2,4,5-T	6000 ppm	FS	YS	E,M
		2,4,5-T	12,000 ppm	FS	E	
		Comb. esters	6000 ppm	FS	YS	E,M
Gooseberry, northern	Ribes oxyacanthoides	Comb. esters	2000-3000 ppm	FS		MH
		2,4-D esters and salts	2000 ppm	FS	M,MH	
Grape, riverbank	Vitis riparia	2,4-D	3000 ppm	FS	YS,E,M,MH,L	
		2,4-D	1000 ppm	CS	D	
		Comb. esters	1000+ ppm	FS	YS,E,M,MH,L	
		2,4,5-T	2000 ppm	FS	L	
		2,4,5-T	96,000 ppm	CS	E	
		Ammate	1 lb/gal	FS	M	
Greenbrier, common	Smilax rotundifolia	2,4,5-T	8000 ppm (oil)	BS	D	
		Comb. esters	6000 ppm	FS	E,M,MH	
Hackberry	Celtis occidentalis	2,4-D	200,000 ppm	CS	M,MH	
		2,4-D	2000 ppm	FS	YS	

See footnotes at end of table.

Species name		Herbicide[2/]	Concentration or rate[3/]	Kind of appli-cation[4/]	Season at which obtained[5/]	
Common	Scientific				Good control[6/]	Fair control[7/]
Hawthorn	Crataegus spp.	2,4-D	4000 ppm	FS		YS,E,M,MH
		2,4-D	2 lbs ahg (oil)	BS,CS	D,E,M	
		2,4,5-T	1500-4000 ppm	FS		YS,E,M
		2,4,5-T	2 lbs ahg (oil)	BS,CS	D,E,M	
		Comb. esters	4000-6000 ppm	FS	E,M,MH	
		" "	2 lbs ahg (oil)	CS	D,E,M	
		" "	8000 ppm (oil)	CS	MH	
		Ammate	3/4-1 lb/gal	FS		M
		"	1/2 lb/gal	CS	D,E,M	
Hazel, beaked	Corylus cornuta	2,4-D	2000 ppm	FS		E,M,MH
		2,4-D	2400 ppm	FS	M	
		2,4-D ammonium salt	5 lbs ahg	FS	M	
		2,4-D	4000 ppm	BS		D
		2,4,5-T	2000 ppm	FS		M,MH
		2,4,5-T	2400 ppm	FS	M	
		Comb. esters	1000-8000 ppm	FS		M,MH
		" "	2400 ppm	FS	M	
		Ammate	50-200 lbs/A	FS		M,MH
		"	3/4-1 lb/gal	FS		M
Hazel, American	Corylus americana	2,4-D	1000-3300 ppm	FS		E,M,MH,L,D
		2,4,5-T	2000-3000 ppm	FS		M,MH
		2,4,5-T	3000 ppm (oil)	BS		D
		2,4,5-T	11 lbs/A (90-W 10-0)	BS	D	D
		Comb. esters	11 lbs/A (oil)	BS		D

See footnotes at end of table.

Species name		Herbicide 2/	Concentration or rate 3/	Kind of application 4/	Season at which obtained 5/	
Common	Scientific				Good control 6/	Fair control 7/
Hickory, shagbark	Carya ovata	2,4-D	3000 ppm	FS		YS
		2,4-D amine	Undiluted commercial	AX	E,M	
		2,4,5-T	8000 ppm (oil)	BS	D	
		Comb. esters	3000 ppm	FS	YS	E,M,MH
		Ammate	3/4 lb/gal	FS	M	
Hickory, bitternut	Carya cordiformis	Comb. esters	11 lbs/A (oil)	BS	M	
Hickory, mockernut	Carya tomentosa	Aminotriazole	6 lbs ahg	FS	M	
Honeysuckle, hairy	Lonicera hirsuta	2,4-D	2400 ppm	FS		M
		2,4,5-T	8 lbs ahg (emul.)	BS	D	
		Comb. esters	8 lbs ahg (emul.)	BS	D	
Hophornbeam, eastern	Ostrya virginiana	2,4,5-T	10,000 ppm (oil)	BS	D	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
Hornbeam, American	Carpinus caroliniana	2,4,5-T	4 lbs ahg (oil)	AX	All seasons	

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of appli-cation[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Juneberry	Amelanchier alnifolia	2,4-D	1100-3300 ppm	FS		M,MH,L
		2,4-D esters and salts	1-4 lbs/A	FS		E,M
		Comb. esters	2000 ppm	FS	MH	
		2,4,5-T	3000 ppm	FS	YS,E,M,MH,L	
		Ammate	50-200 lbs/A	FS		M,MH
		Ammate	3/4-1 lb/gal	FS	YS,M	
Labradortea	Ledum groenlandicum	2,4-D	38,400 ppm	FS		MH
		2,4,5-T	38,400 ppm	FS		MH
		2,4,5-T	30 lbs/A (oil)	FS	MH	
		Comb. esters	19,200-38,400 ppm	FS		MH
Laurel, swamp	Kalmia polifolia	2,4-D	38,400 ppm	FS		MH
		2,4,5-T	38,400 ppm	FS		MH
		Comb. esters	38,400 ppm	FS		MH
Leatherleaf	Chamaedaphne calyculata	2,4-D	38,400 ppm	FS		MH
		2,4-D	5 lbs/A (oil)	FS	MH	
		2,4,5-T	19,200 ppm	FS		MH
		Comb. esters	19,200 ppm	FS		MH
Lingonberry	Vaccinium vitis-idaea minus	2,4-D	9600 ppm	FS		MH
		Comb. esters	19,200 ppm	FS		MH

See footnotes at end of table.

Species name		Herbicide 2/	Concentration or rate 3/	Kind of application 4/	Season at which obtained 5/	
Common	Scientific				Good control 6/	Fair control 7/
Locust, black	Robinia pseudoacacia	2,4-D	3000 ppm	FS	YS,E,M	MH,L
		2,4-D esters and amines	2 lbs/A	FS		M,MH
		2,4,5-T	1500 ppm	FS	YS,E,M	MH,L
		2,4,5-T	2000 ppm	AX	L	
		Comb. esters	3000-6000 ppm	FS	E,M,MH	
Maple, red	Acer rubrum	2,4,5-T	2000 ppm	FS		M
		2,4,5-T	5000 ppm (oil)	BS	M,MH	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		Comb. esters	6000 ppm	FS	YS,E,M,MH	
		" "	8000 ppm (oil)	CS	MH	
		" "	20,000 ppm (oil)	BS	MH	
		2,4,5-TP	3 lbs ahg	FS	MH	
		Ammate	3/4-1 lb/gal	AX		M
		Ammate	2-4 lbs/gal	FS	M,MH	
Maple, mountain	Acer spicatum	2,4,5-T	2% (oil)	BS	D	
		2,4,5-T	4% (oil)	BS	E	
		Comb. esters	8000 ppm (oil)	CS	MH	
		2,4,5-TP	3 lbs ahg	FS	MH	
Maple, silver	Acer saccharinum	Comb. esters	3000 ppm	FS	E,M,MH	
		2,4,5-T	1000 ppm	FS	L	

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Maple, sugar	Acer saccharum	2,4-D	8000 ppm (oil)	CS		D
		2,4,5-T	3000 ppm	FS		E,MH
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4,5-TP	3 lbs ahg	FS	MH	
Maple, striped	Acer pensylvanicum	Comb. esters	3000 ppm	FS		YS,E
Oak, black	Quercus velutina	2,4,5-T	4 lbs ahg (oil)	AX		All seasons
		Aminotriazole	6 lbs ahg	FS	M	
Oak, blackjack	Quercus marilandica	2,4,5-T	2 lbs/A	FS (aerial)		E
		Comb. esters	3 lbs/A	FS (aerial)		E
		2,4,5-T	16 lbs ahg (oil)	AX		D
Oak, bur	Quercus macrocarpa	2,4-D	1500 ppm	FS		M,MH
		2,4,5-T	1000-2000 ppm	FS		M
		Comb. esters	$1\frac{1}{2}$ lbs/A	FS		M,MH
		" "	4 lbs ahg (oil)	FS	L	
		2,4,5-TP	11 lbs ahg	FS	MH	
Oak, mixed red and white	Quercus spp.	2,4-D	48 lbs ahg (oil)	BS		D
		2,4,5-T	4-48 lbs ahg (oil)	BS		D
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4-D amine	4 lbs/gal	AX	E,M	

See footnotes at end of table.

Species name		Herbicide[2/]	Concentration or rate[3/]	Kind of application[4/]	Season at which obtained[5/]	
Common	Scientific				Good control[6/]	Fair control[7/]
Oak, northern red	Quercus rubra	2,4-DP	4 lbs ahg	FS	M	
		2,4-D amine	4 lbs/gal	AX	E,MH	
		2,4-D	4 lbs/gal (oil)	AX	E,MH	
		2,4,5-T	4 lbs ahg	FS	M	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4,5-T	1 lb/A	FS (aerial)	M	
		2,4,5-TP	4 lbs ahg	FS	M	
		Comb. esters	6000 ppm	FS	YS,E,M,MH	
		" "	4 lbs ahg (oil)	FS (aerial)	L	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Oak, northern pin	Quercus ellipsoidalis	2,4-DP	4 lbs ahg	FS	M	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4,5-T	4 lbs ahg	FS	M	
		2,4,5-T	1 lb/A (emul.)	FS (aerial)	M	
		Comb. esters	1 lb/gal (oil)	FS (aerial)	L	
		2,4,5-TP	3-4 lbs ahg	FS	M,MH	
		Aminotriazole	6 lbs ahg	FS	M	
		Ammate	Crystals	AX	M	
Oak, scarlet	Quercus coccinea	Comb. esters	4000-6000 ppm	FS	E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH

See footnotes at end of table.

Species name		Herbicide[2]	Concentration or rate[3]	Kind of application[4]	Season at which obtained[5]	
Common	Scientific				Good control[6]	Fair control[7]
Oak, white	Quercus alba	2,4-D	4 lbs/gal	AX	E,MH	
		2,4-D amine	4 lbs/gal	AX	E,MH	
		2,4-DP	4 lbs ahg	FS	M	
		2,4,5-T	1500 ppm	FS	YS,E,M	MH,L
		2,4,5-T	4 lbs ahg	FS	M	
		2,4,5-T	1 lb/A (emulsion)	FS (aerial)	M	
		2,4,5-T	4 lbs ahg (oil)	AX	All seasons	
		2,4,5-T	16 lbs ahg	BS	D	
		2,4,5-TP	3 lbs ahg	FS	MH	
		Comb. esters	4000-6000 ppm	FS	E,M,MH	
		Aminotriazole	6 lbs ahg	FS	M	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Pine, eastern white	Pinus strobus	2,4-D	6000+ ppm	FS	YS	
		2,4-D	8 lbs ahg (oil)	BS	MH	
		2,4,5-T	8 lbs ahg (oil)	BS	MH	
		Comb. esters	3000 ppm	FS		YS,E
		Ammate	1 lb/gal	FS	YS	
Pine, red	Pinus resinosa	Comb. esters	3000 ppm	FS		YS,E,M
		Ammate	80 lbs/A	FS	YS	
Poison ivy, common	Toxicodendron radicans	2,4-D	2000-3000 ppm	FS	YS	E,M,MH
		2,4,5-T	1000-2000 ppm	FS	YS,E,M,MH	L
		Comb. esters	1000-3000 ppm	FS	YS,E,M,MH	L
		Ammate	100,000 ppm	FS	E	
		Aminotriazole	2 lbs ahg	FS	M	

See footnotes at end of table.

Species name		Herbicide 2/	Concentration or rate 3/	Kind of application 4/	Season at which obtained 5/	
Common	Scientific				Good control 6/	Fair control 7/
Plum, American	Prunus americana	2,4-D	2000 ppm	FS	E	M,MH
		Comb. esters	6000 ppm	FS	E,M,MH	
Plum, Canada	Prunus nigra	2,4,5-T	2000 ppm	FS	YS,E,M,MH	
Poplar, balsam	Populus balsamifera	Comb. esters	2000 ppm	FS	MH	
		2,4-D	1½ lbs/A	FS		YS,E
Prickly-ash	Zanthoxylum americanum	2,4-D	2000-8000 ppm	FS		M,MH
		2,4-D	14 lbs ahg (oil)	BS	D	
		2,4-D	4.8 lbs ahg	CS		M,L
		2,4,5-T	2-4.8 lbs ahg	FS	M,L	
		Comb. esters	2000-8000 ppm	FS		M,MH
		MCP	14 lbs ahg (oil)	BS	D	
		MCP	4.8 lbs ahg	FS,CS		M,L
Raspberry, black	Rubus occidentalis	Comb. esters	3000 ppm	FS	YS,E,M,MH,L	
		Ammate	50-200 lbs/A	FS		M,MH
Redcedar, eastern	Juniperus virginiana	Comb. esters	6000 ppm	FS		YS,E,M,MH
Rose, wild	Rosa spp.	2,4,5-T	1/2-2 lbs/A	FS		M
		Comb. esters	2000 ppm	FS		MH
		Ammate	50-200 lbs/A	FS		M,MH

See footnotes at end of table.

Species name: Common	Species name: Scientific	Herbicide[2/]	Concentration or rate[3/]	Kind of application[4/]	Season at which obtained[5/]: Good control[6/]	Season at which obtained[5/]: Fair control[7/]
Sassafras	Sassafras albidum	2,4-D	3000 ppm	FS	YS,E,M,MH,L	
		2,4-D	2% (oil)	BS	M	
		2,4,5-T	1500+ ppm	FS	YS,E,M,MH,L	
		2,4,5-T	2% (oil)	BS	M	
		Comb. esters	4000+ ppm	FS	E,M,MH	
		Ammate	2-4 lbs/gal	FS	M,MH	
Snowberry, western	Symphoricarpos occidentalis	2,4-D	1-3 lbs ahg	FS	E,M	MH
		2,4,5-T	2.5 lbs ahg	FS	E,M	
		2,4-D (emulsifiable acid)	2.5 lbs ahg	FS	E,M	
		Comb. esters	2000-4000 ppm	FS		E,M,MH
		2,4,5-TP	2.5 lbs ahg	FS	E,M	
		Aminotriazole	2 lbs ahg	FS	E,M	
Spirea, narrow-leaf meadowsweet	Spiraea alba	2,4-D acid	1000 ppm	FS		MH
		Comb. esters	1000 ppm	FS		MH
		2,4,5-T	4800 ppm	FS		MH
Sumac, staghorn	Rhus typhina	2,4-D	3000 ppm	FS	YS,E,M,MH,L	
		2,4,5-T	15,000 ppm	FS	YS,E,M,MH,L	
		Comb. esters	3000 ppm	FS	YS,E,M,MH,L	
		Ammate	3/4 lb/gal	FS	M,MH	
Sumac, smooth	Rhus glabra	Comb. esters	6000 ppm	FS	E,M,MH	
		2,4-D	2000 ppm	FS	YS,E,M,MH	
		2,4,5-T	1000-2000 ppm	FS	YS,E,M,MH,L	
		Ammate	3/4 lb/gal	FS	M,MH	
Sweetfern	Comptonia peregrina	2,4-D	3000 ppm	FS	E,MH	
		Ammate	2-4 lbs/gal	FS	M,MH	
		CMU	12 lbs/A	Soil spray	D,E,M	

See footnotes at end of table.

Species name		Herbicide2/	Concentration or rate3/	Kind of application4/	Season at which obtained5/	
Common	Scientific				Good control6/	Fair control7/
Sycamore, American	Platanus occidentalis	2,4,5-T	8 lbs ahg (oil)	BS	D	
Wahoo, eastern	Euonymus atropurpureus	2,4,5-T	2000 ppm	FS		L
Walnut, black	Juglans nigra	Comb. esters	3000 ppm	FS	YS	E,M,MH
Willows	Salix spp.	2,4-D	3000 ppm	FS	YS,E,M	MH,L,D
		2,4-D	3000 ppm	CS	YS,E	M,MH,L
		2,4-D amine	Undiluted commercial	AX	E,M	
		2,4,5-T	2000 ppm	FS	YS,E,M,MH	L
		Comb. esters	1000-4000 ppm	FS	YS,E,M,MH	L
		Ammate	3/4-1 lb/gal	FS		M,MH
Witchhazel	Hamamelis virginiana	Comb. esters	3000 ppm	FS		M,MH

1/ Based upon a large number of sources, some of which were conflicting.
2/ Unless indicated, these are esters formulations.
3/ Ahg--acid equivalent per 100 gallons; ppm--parts per million; diluent is water unless otherwise stated.
4/ FS--foliage spray; CS--cut surface; AX--frills, girdles, or gashes; BS--basal spray.
5/ YS--young seedlings; E--early season; M--mid-season, growth succulent; MH--mid-season, growth not succulent; L--late season; D--dormant.
6/ Complete top-kill by one application. Satisfactory root kill often requires additional treatments.
7/ Complete top-kill not obtained with one application.
8/ Combination of 2,4-D and 2,4,5-T, often equal parts of each.
9/ DNOSP--dinitro ortho secondary butyl phenol.

Table B.--Partial list of producers of herbicides[1/]

Company	Herbicides produced
Allied Chemical and Dye Corp. 40 Rector Street New York 6, N. Y.	2,4-D, 2,4,5-T, TCA, DNOSP
American Chemical Paint Co. Agricultural Chemicals Division Ambler, Pennsylvania	2,4-D, 2,4,5-T, 2,4,5-TP, MCP, TCA, Aminotriazole, polychlorobenzoics
American Cyanamid Co. Agricultural Chemicals Division 30 Rockefeller Plaza New York 20, N. Y.	Aminotriazole
Chemagro Corporation 437 Fifth Avenue New York 16, N. Y.	2,4-D, 2,4,5-T
Chipman Chemical Co., Inc. Chicago, Illinois	2,4-D, 2,4,5-T, MCP
Diamond Alkali Co. 300 Union Commerce Building Cleveland 14, Ohio	2,4-D, 2,4,5-T
The Dow Chemical Company Midland, Michigan	2,4-D, 2,4,5-T, 2,4,5-TP
E. I. duPont de Nemours & Co., Inc. Grasselli Chemicals Department Wilmington 98, Delaware	Ammate, CMU
Monsanto Chemical Company 1700 South Second Street St. Louis 4, Missouri	2,4-D, 2,4,5-T, MCP
Standard Agricultural Chemicals, Inc. 13th & Jefferson Streets Hoboken, New Jersey	2,4-D, 2,4,5-T, MCP, TCA, DNOSP

See footnote at end of table.

Company	Herbicides produced
Standard Oil Company Chicago, Illinois	2,4-D, 2,4,5-T
Thompson-Hayward Chemical Co. Kansas City 8, Missouri	2,4-D, 2,4,5-T, TCA, Aminotriazole
Woodbury Chemical Company 1590 West 12th Avenue Denver, Colorado	2,4-D, 2,4,5-T, CMU, TCA, Aminotriazole

1/ This list is included for information only. It does not purport to be complete, and the listing herein implies neither discrimination against nor endorsement of dealers or their products.

Table C.--Partial list of manufacturers of spraying equipment[1/]

John Bean Division
Food Machinery & Chemical Corp.
Lansing 4, Michigan

E and E Sprayer Company
Waverly, Nebraska

Original Enderes Company
Guttenberg, Iowa

The Engine Parts Mfg. Co.
1360 West 9th Street
Cleveland 13, Ohio

Hanson Chemical & Equipment Co.
Beloit, Wisconsin

The Hardie Manufacturing Co.
Hudson, Michigan

Kupfer Products, Inc.
Madison, Wisconsin

Monarch Manufacturing Works, Inc.
2501 East Ontario Street
Philadelphia 34, Pennsylvania

Northwest Agricultural Aviation Corp.
Choteau, Montana

Sorenson Manufacturing Co.
Worthington, Minnesota

Spraying Systems Company
3275 Randolph Street
Bellwood, Illinois

Tryco Manufacturing Co., Inc.
Forsyth, Illinois

W. A. Westgate Co.
P. O. Box 445
Davis, California

1/ This list is included for information only. It does not purport to be complete, and the listing herein implies neither discrimination against nor endorsement of dealers or their products.

SOME RECENT STATION PUBLICATIONS

Tests of a Portable Wood Chipper, by J. L. Arend, R. N. Smith, and R. A. Ralston. Sta. Paper 30, 37 pp., illus. 1954. (Processed.)

Forest Statistics of Minnesota, 1953, by Paul C. Guilkey, Bernard Granum, and R. N. Cunningham. Sta. Paper 31, 36 pp., illus. 1954. (Processed.)

A Review of Literature Relating to Quaking Aspen Sites, by M. L. Heinselman and Z. A. Zasada. Sta. Paper 32, 61 pp. 1955. (Processed.)

Oak Wilt Damage--A Survey in Central Wisconsin, by Ralph L. Anderson and D. D. Skilling. Sta. Paper 33, 11 pp., illus. 1955. (Processed.)

Forest Management Lessons From a 1949 Windstorm in Northern Wisconsin and Upper Michigan, by J. H. Stoeckeler and Carl Arbogast, Jr. Sta. Paper 34, 11 pp. 1955. (Processed.)

The Forest Insect Situation, Lake States, 1955, by L. C. Beckwith and H. G. Ewan. Sta. Paper 35, 15 pp., illus. 1956. (Processed.)

The Timber Resource of North Dakota, by John R. Warner and Clarence D. Chase. Sta. Paper 36, 39 pp., illus. 1956. (Processed.)

Lake States Timber Resources, by R. N. Cunningham and Survey Staff. Sta. Paper 37, 31 pp. 1956. (Processed.)

Publications of the Lake States Forest Experiment Station, 1923-1955. Sta. Paper 39, 130 pp. 1956. (Processed.)

Guide for Selecting Superior Forest Trees and Stands in the Lake States. Sta. Paper 40, 32 pp., illus. 1956. (Processed.)